CANADA
DEPARTMENT OF MINES
HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN McLEISH, DIRECTOR

INVESTIGATIONS IN CERAMICS AND ROAD MATERIALS

(Testing and Research Laboratories)

1930 and 1931

PAGE

Introduction: by Howells Fréchette........................... 1

CERAMICS:

I. Ceramic bodies for electrical heating devices: by L. P. Collin.. 5

II. Colour control of brick: by L. P. Collin.............. 29

III. Roofing-tile clays and shales of eastern Canada: by J. F. McMahon...................................... 37

IV. The production of shapes from soapstone dust: by J. G. Phillips.. 67

V. The continuation of the investigation of the treatment of clays to overcome drying defects: by J. G. Phillips.. 75

ROAD MATERIALS:

VI. Road gravels in Quebec: by R. H. Picher............. 84

BIBLIOGRAPHY.. 165

No. 726

OTTAWA
J. O. PATENAUDE, ACTING KING'S PRINTER
1933

CANADA

DEPARTMENT OF MINES

HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

JOHN McLEISH, DIRECTOR

INVESTIGATIONS

IN

CERAMICS AND ROAD MATERIALS

(Testing and Research Laboratories)

1930 and 1931

PAGE

Introduction: by Howells Fréchette 1

CERAMICS:

I. Ceramic bodies for electrical heating devices: by L. P. Collin 5

II. Colour control of brick: by L. P. Collin 29

III. Roofing-tile clays and shales of eastern Canada: by J. F. McMahon 37

IV. The production of shapes from soapstone dust: by J. G. Phillips 67

V. The continuation of the investigation of the treatment of clays to overcome drying defects: by J. G. Phillips 75

ROAD MATERIALS:

VI. Road gravels in Quebec: by R. H. Picher 84

BIBLIOGRAPHY 165

No. 726

OTTAWA

J. O. PATENAUDE, ACTING KING'S PRINTER

1933

Annual reports on Mines Branch investigations are now issued in four parts, as follows:—

Investigations of Mineral Resources and the Mining Industry.

Investigations in Ore Dressing and Metallurgy (Testing and Research Laboratories).

Investigations of Fuels and Fuel Testing (Testing and Research Laboratories).

Investigations in Ceramics and Road Materials (Testing and Research Laboratories).

Other reports on Special Investigations are issued as completed.

MINES BRANCH INVESTIGATIONS IN

CERAMICS AND ROAD MATERIALS, 1930 and 1931

INTRODUCTION

Howells Fréchette

Chief of Ceramics and Road Materials Division

During the two years' period which this report covers there have been several major investigations brought to completion and several new investigations undertaken.

In the Ceramics Section the policy has been to study outstanding problems of the clayworking industries with a view to aiding existing industries in the technique of manufacture, to encourage through research the production of lines of ware of high quality to compete with imported products in the Canadian market, to promote the use of Canadian raw materials to their best advantage, and to make available information regarding the resources of clays and shales of Canada.

In the Road Materials Section the investigations have been mainly systematic examinations of the rock and gravel deposits throughout Canada for the purpose of determining the location of material for road construction and maintenance, and the relative suitability of these materials for such use. In many cases the areas surveyed have been along the routes of proposed main highway construction and in territories served by important secondary roads. The information has been presented in a form useful to provincial highway departments and county engineers. During the past few years connecting surveys have been made for the purpose of filling in gaps not included in these route surveys and it is hoped that the new data compiled with previously published data will considerably broaden the usefulness of the work.

Ceramics Section

In the report for 1928 and 1929[1] there was a preliminary report by L. P. Collin on investigations upon ceramic bodies for electrical heating devices, the purpose of which was to develop ceramic bodies suitable for refractory shapes for supporting heating elements. In such products resistance to temperature shock and mechanical strength are prime requisites. The research carried out by Mr. Collin has resulted in the formulation of a number of bodies possessing these characteristics to a high degree. Mr. Collin's final report appears on page 5. In this investigation one series of mixtures, although not of particularly great resistance

[1] Investigations in Ceramics and Road Materials, 1928–1929, Mines Branch, No. 722, p. 4.

to thermal shock, was found to be extremely tough and resistant to wear. Recently there have been several enquiries for ceramic bodies suitable for the manufacture of porcelain, pebble-mill balls and liners. Further work on the series mentioned above has developed porcelains superior to those on the market for use in pebble-mills. This sub-investigation has not yet been fully completed.

The investigation on colour control of brick conducted by L. P. Collin, which includes the work on the production of grey brick already reported upon in part,[1] has resulted in the commercial production of bricks of various colours in the Maritime Provinces that are expected to completely displace imported face-brick in that market. Mr. Collin's report on page 29 covers all phases of the investigation.

An investigation to determine and study the basic physical properties of Canadian building brick has been undertaken. Many samples have already been collected and laboratory tests are now under way with Mr. Collin in charge.

As already reported,[2] in 1929, J. F. McMahon collected samples of a number of clays and shales from the Maritime Provinces, to determine their suitability for the manufacture of roofing-tile. These have since been tested to determine their working properties, their firing behaviour, and the characteristics of finished bodies made from them and fired under various heat-treatments. The results of these tests, as well as the recorded characteristics of the most likely materials from Quebec and Ontario, have been very carefully considered for the purpose of ascertaining the most suitable raw materials for roofing-tile in eastern Canada. In J. F. McMahon's report which appears on page 37, he draws attention to certain shales along the northeastern coast of New Brunswick, which tests show to be particularly well suited for the production of roofing-tiles and vitrified quarry-tiles.

J. F. McMahon has written for separate publication a full report on his investigation on clay-gathering and handling. His report will contain a discussion of various methods of winning clay, with analyses of cost, under a wide range of conditions.

In connection with the general investigation of the refractory resources and industry of Canada, on which he is now engaged, Mr. McMahon has prepared a summary of the published information regarding our resources of fireclays. This has been issued in the mimeographed Memorandum Series.[3] In 1931 he spent several weeks in the Prairie Provinces examining and sampling occurrences of fireclay and visiting firebrick plants. Besides testing these clays he has conducted experiments on the making of silica firebrick from quartzites from Nova Scotia and Quebec.

With a view to developing uses for waste dust and scrap from soapstone quarry operations, J. G. Phillips studied binders suitable for use in pressing soapstone powder into marketable shapes. His report, page 67, shows that with the use of sodium silicate of suitable grade, shapes may be produced about equal in strength to that of natural soapstone.

---

1 Investigations in Ceramics and Road Materials, 1928-1929, Mines Branch, No. 722, p. 22.
2 Investigations in Ceramics and Road Materials, 1928-1929, Mines Branch, No. 722, p. 2.
3 Refractory Clays in Canada, by J. F. McMahon, Mines Branch, Memorandum Series No. 57.

In the continuation of investigation on the treatment of clays to overcome drying defects, Mr. Phillips has studied the inherent properties of defective clays, and the cause of cracking during drying of several notably bad-drying clays has been ascertained. In his report on page 75, the method of study is described and the degree to which the various clays are defective in drying properties is shown. The kind and amount of chemical treatment required to render the various clays safely dryable is given. Several examples are cited of cases where chemical treatment has been applied commercially to overcome drying troubles.

During the two years covered by this report, in addition to the samples collected by officers of the Division, 275 samples of clay from southern Saskatchewan, collected by Dr. F. H. McLearn of the Geological Survey, were tested for refractoriness and 158 of these were subjected to more extensive tests for the purpose of estimating their commercial value.[1] These tests were conducted by J. G. Phillips.

One hundred and ninety-six samples of clays and shales, 8 samples of mineral pigment, 6 samples of silica, 5 samples of diatomaceous earth, and 6 samples of other minerals, all submitted by the general public, were tested and reported upon as to possible commercial uses.

Rather extensive tests were carried out on samples of china clay and silica sand, said to have been collected from holdings on the Missinaibi River, Ontario. Both the clay and the silica sand gave indications of being of high grade and were considered worthy of investigation as to possibilities for the manufacture of white ware and allied ceramic products.

The research on the manufacture of high-grade, refractory brick from Canadian magnesite has been continued. This investigation is being made in co-operation with the National Research Council.

Road Materials Section

In 1929, R. H. Picher began a series of connecting or supplementing surveys of the road-gravel resources of the Province of Quebec. These surveys were conducted throughout the districts intervening between the areas of trunk-route surveys made previously, so as to complete data regarding road gravels in the populated parts of the province. This work was continued during 1930 and completed in 1931. Mr. Picher's report appears on page 84. It is proposed to prepare for separate publication a final report covering a complete review of the road-gravel resources of the Province of Quebec with a tabulation of their properties showing their relative value for road service.

[1] Summary Report of the Geological Survey, 1930, Part B, p. 31.

I

CERAMIC BODIES FOR ELECTRICAL HEATING DEVICES

L. P. Collin

Canada is fortunate in possessing enormous waterpower resources for the development of electricity. In recent years the development of hydro-electric power has been progressing by leaps and bounds. As a result of this, and because much of this development is either publicly owned or controlled, the average householder in Canada is able to purchase electrical power at a much lower rate than the people of any other country in the world with possibly one or two exceptions. This supply of cheap electrical energy has been responsible for the widespread use of electrical appliances in the home. There are few urban homes in Canada today where use is not made of many electrical devices to save time and labour.

One of the most important of these appliances is the modern electric cooking-stove. Due to the foresight and initiative of Canadian stove manufacturers, many makes of electrical ranges are on the market at very reasonable prices. In addition to this, a considerable export trade has been developed, and Canadian-made electrical ranges and heating plates are shipped to all parts of the world. The stove manufacturer, however, is dependent on other manufacturers for the refractory plates used to support and protect the electrical heating-element. These are a ceramic product and require certain characteristics different from those of porcelain and other ceramic materials so commonly used in electrical apparatus. Because of the fact that these ceramic products have been in use only for a short time, and that even today their production is such a small part of the ceramic industries, they have been subject to very little technical study, and scarcely any results have been published. Manufacturers have, therefore, been keenly desirous that investigational work be carried out for the purpose of showing suitable mixtures to use, and if possible to formulate bodies that would make a superior product to that now on the market.

The physical characteristics required for these refractory plates are a high resistance to sudden temperature change and good electrical insulation. An electric stove-plate is subjected to heating and cooling several times a day when in use and the time required to go from room temperature to 400° or 500°C. is only a few minutes. Further, when these plates are red hot in some portions, water or other liquid is likely to be spilled over them. Such conditions of service require a product extremely high in resistance to the disintegrating effect of rapid and great changes in temperature. Effective electrical insulation is a property inherent in practically all ceramic bodies at the low voltages used in electric stoves. Mechanical strength is another physical characteristic of importance to the extent only, however, that the plate is able to withstand the handling for installing and the impact imposed by placing cooking utensils on the stove. Colour of the product is important, and whereas white is the most desirable many shades approaching white are quite satisfactory.

Other characteristics of importance concern principally the problems of manufacture and not the requirements of service. The unburned body must possess sufficient plasticity and green strength that it may be satisfactorily pressed in the semi-dry state and withstand handling until it has been burned. The firing shrinkage must be such that plates can be burned without excessive loss of ware from firing cracks, warpage, or variation in size. After considering all of the above, it seemed that the property of withstanding temperature shock was by far the most important and that a raw material known to produce such a property when compounded in a ceramic body should be used.

In reviewing the literature dealing especially with ceramic products and raw materials, it was found that magnesium oxide, in one form or another, was given particular mention because bodies produced from it were tough and resistant to thermal shock. Magnesium oxide may be introduced into ceramic bodies as magnesium carbonate, magnesia, fused magnesia, magnesite, talc, or as a calcine. In this investigation two sources of magnesium oxide were used, namely talc and a calcined hydro-magnesite from British Columbia. Talc possesses the advantage of not lessening plasticity and has a relatively low burning shrinkage. The calcined hydro-magnesite, on the other hand, while it may lessen plasticity and have a high burning shrinkage, lacks the high silica content of talc. Free silica, unless fused, has a high coefficient of expansion, as well as an aptitude to change form accompanied by expansion, and was considered undesirable as a component in bodies of this type. It was felt, therefore, that the investigation should include magnesium oxide from these two sources only, combined with various percentages of china clay and ball clay. The idea of using a calcine was not considered in the initial work but is discussed later.

Raw Materials

The talc was of Canadian origin and, although of good colour and quality, the relatively high percentage of calcium oxide made its successful use for the purpose desired somewhat doubtful. A chemical analysis of this talc follows:—

SiO_2	46·20
Al_2O_3	2·21
Fe_2O_3	0·79
CaO	8·60
MgO	27·15
K_2O	......
Na_2O	......
Ignition loss	15·21
	100·16

The hydro-magnesite from British Columbia, after calcination at approximately 1000°C., gave the following chemical analysis:—

SiO_2	4·60
Al_2O_3	1·23
Fe_2O_3	0·47
CaO	......
MgO	93·65
Ignition loss	0·45
	100·40

This particular hydro-magnesite was purer than the average run, in many cases the calcium oxide content being between 0·5 and 2·0 per cent.

An English ball clay and English china clay were used as no similar Canadian clays were available on the market at the time the investigation was begun. The chemical analyses of these two clays were as follows:—

—	English ball clay	English china clay
SiO_2	49·50	45·70
Al_2O_3	30·43	39·11
Fe_2O_3	2·37	1·89
CaO	0·00	0·00
MgO	0·94	0·00
K_2O	0·97	0·10
Na_2O	1·05	0·91
Ignition loss	14·90	11·70
	100·16	99·41

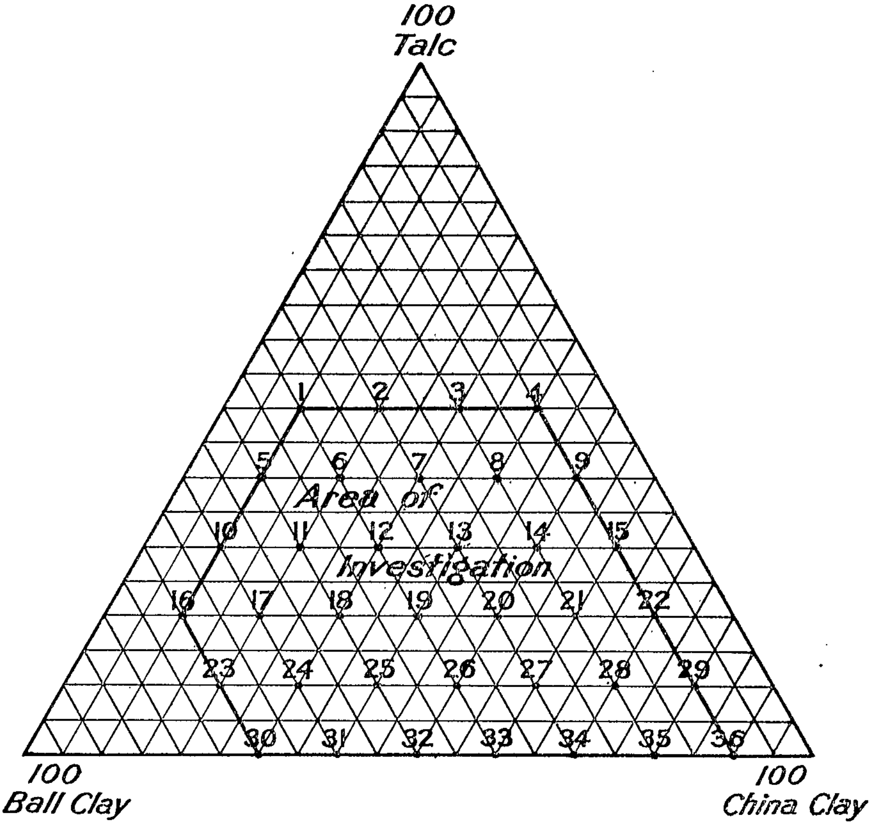

Figure 1. Series I Mixtures

Body Mixtures

The mixtures used are shown in the triaxial diagrams in Figures 1 and 2, and the percentage composition in Tables Nos. I and II. In Series I the talc content was from 0 to 50 per cent, ball clay from 10 to 70 per cent, and china clay from 10 to 80 per cent. In Series II in which the calcined hydro-magnesite was used, the variations were from 0 to 40 per cent magnesite, from 10 to 70 per cent ball clay, and from 10 to 70 per cent china clay. The field in each case was considered sufficient to show the effect of mixtures of magnesium oxide, ball clay, and china clay, in so far as their use might be of value in the compounding of bodies for electrical heating devices. As is shown in the accompanying figures, Series I contained 35 mixtures and Series II, 24.

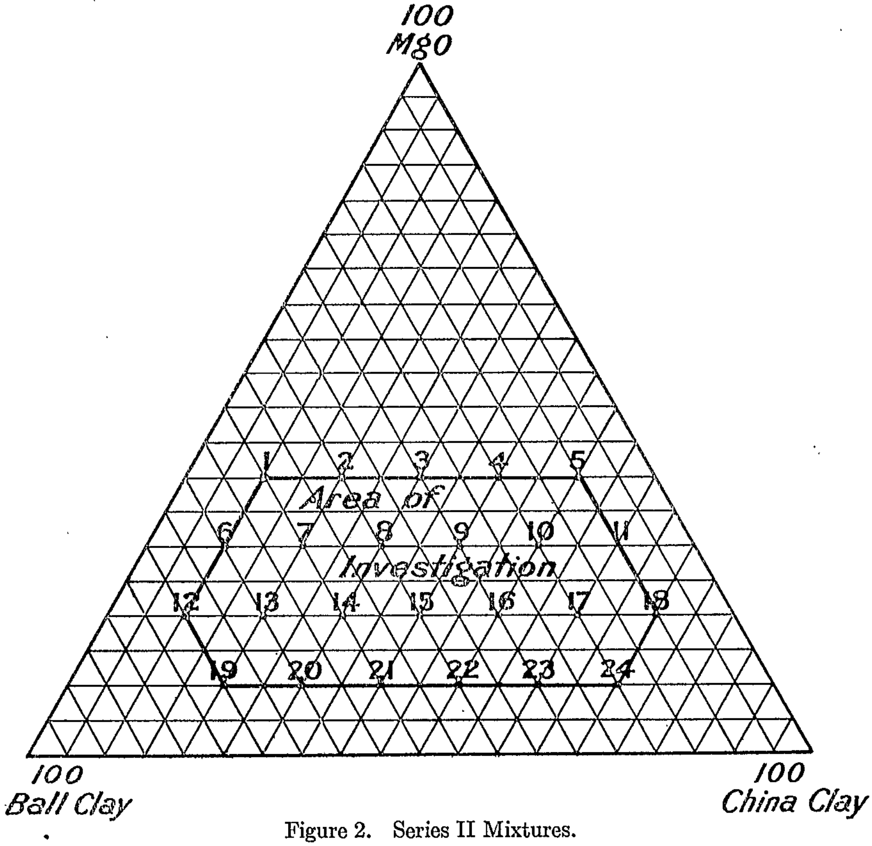

Figure 2. Series II Mixtures.

Preparation of Bodies

Two-thousand-gramme batches of each mixture were prepared and the body components were weighed to an accuracy of one-tenth of one gramme. In Series I these mixtures were blunged in a small power-blunger for one hour. Sufficient water was used in the blunging in every case to bring the body to a smooth slip, thick enough to prevent settling of any of the components. After this blunging the slip was passed through a 100-mesh screen and was then ready for filter-pressing. In Series II, due to the possibility of coagulation of the magnesium oxide particles, the mixtures were passed through a 100-mesh screen after one hour's blunging and were then reblunged for one-half hour and rescreened through a 100-mesh screen after which they were considered ready for filter-pressing.

The mixtures of both Series I and Series II were then put through a small laboratory filter-press, after which they were placed in electric ovens to dry. Particular care was taken in the drying that in no case did the temperature exceed 105°C., thus making sure that no part of the plasticity was lost in the drying operation. After remaining in these ovens for a period of 24 hours, the body mixtures were removed and ground to pass a 30-mesh screen. They were then moistened sufficiently to form a ball when pressed firmly in the hand and were transferred to damp cupboards. The conditions in these damp cupboards were such that after a 24-hour ageing, the water content was the same as originally. The percentage of water necessary to develop the best plasticity varied greatly, and was much higher than that originally considered in dry-press bodies.

Design of the Test Pieces

Much thought was given to the design of the test pieces and the fina shapes adopted were those of a thin, concentrically ridged disk for the thermal shock tests, and a plain cylinder for the toughness test as shown in Plate I A. A test piece more nearly approaching the commercial stove-plate in size and design would have been a much more satisfactory shape, but such a test piece could not be made because of limitations of the laboratory equipment. The concentric ridges on the test piece for determining the effect of temperature change gave the specimen a variation in thickness such as is found in all electrical stove-plates. A hydraulic press was used for forming the cylinders and disks. The cylinders were $\frac{15}{16}$ inch in diameter and as close as possible to $1\frac{1}{4}$ inches high so that the burned test piece would be at least 1 inch in height. The disks were made just under $\frac{1}{2}$ inch thick in a die $1\frac{1}{2}$ inches in diameter. Thirty cylinders and fifteen disks were pressed from each mixture in both Series I and II.

Fusions and Trial Burns

Inasmuch as the eutectic temperature of the three oxides MgO, Al_2O_3, SiO_2, has been reported to be near cone 12 (1310° C.), it was necessary to determine fusion temperatures of these mixtures as an aid in deciding the proper burning temperature, and to make sure that no burning temperature would be chosen higher than the lowest fusion temperature. The results of these fusions as expressed in pyrometric cone equivalents are shown in Table III. After noting the wide variation in fusion temperatures, it was deemed necessary to run a trial burn and draw specimens of each mixture at such a temperature during the burn as would be most likely to cover the best firing range. In carrying this out three cylinders of each body mixture were to be drawn at each of three specified standard cones. The selections of cones for the various bodies are shown in Table IV. The burning curve was such that cone 12 would be reached in approximately 24 hours. The test specimens were placed in a large muffle in a down-draught gas kiln. In studying the burning curve in Figure 3, it will be noted that the lower cones, 04, 01 and 2 came down at very short intervals. This was because of insufficient capacity of the muffle, and in order to get all of the test pieces in, it was necessary to set those to be drawn out first very close to the wicket, which area was considerably cooler than the rest of the muffle. Thus when cone 04 was reached at the wicket, cone 01 was bending directly behind this set of draw-trials and cone 2 was bending when cone 01 was down. However, as the cones were set directly on the test pieces and each set covered only a comparatively small area, any inequalities in temperature in any given set were not sufficient to affect the results. As the various sets of test pieces were drawn they were placed in a kiln maintained at a good red heat and were cooled slowly.

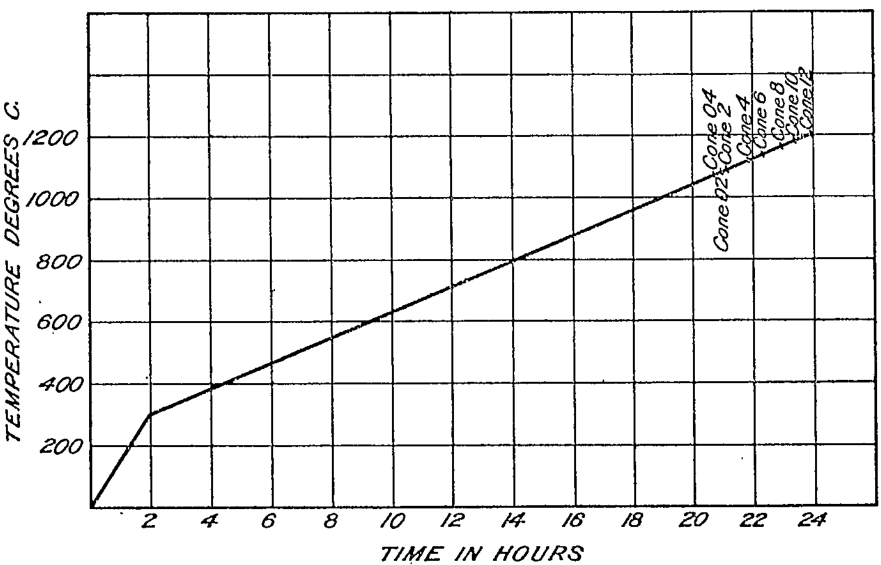

Figure 3. Burning curve.

Final Burns

The test pieces from the trial burns were examined for hardness, and the toughness and the absorptions were determined. After taking into consideration the fusions of the body mixtures and the results of these tests, the firing temperatures shown in Tables V and VI were adopted as the most likely to cover the burning range of each mixture. The test pieces were placed in saggers for the final burns and a separate burn was made for each of the following cones: 2, 4, 6, 8, 10 and 12. In every case a burning curve similar to that shown in Figure 3 was followed and the burning time averaged between 24 and 30 hours. After each burn the kiln was allowed to cool 24 hours before the saggers were removed.

a. Test pieces. b. Typical electric stove-plate. c. Page impact testing machine.

Results of Tests

The toughness was determined on the Page impact machine shown in Plate I C. A weight of 1 kilogram was used and the height of drop was increased 1 centimetre for each blow. The number of blows required to cause failure was recorded as the toughness of the material. The figures given in Tables VII and VIII represent the average of three determinations.

Shrinkage percentages were calculated from linear shrinkage of the diameter of the disks. Absorption percentages were made on broken pieces from the impact test and the results of both of these are shown in Tables IX and X.

The tests for resistance to thermal shock were carried out in a small electric furnace of the type using chromel-alumel heating elements. The furnace temperature was maintained at 780° C. A number of test pieces were placed in a wire tray which was put in the furnace for a period of twenty minutes, after which the test pieces were removed and immediately submerged in a tub of cold water. As soon as they were cool they were examined for cracks and were then replaced in the furnace for another twenty-minute heating. In many pieces the initial cracks were so small that they could not be detected by the naked eye and it was necessary to use a binocular microscope. The presence of a crack only large enough to be easily detected by the naked eye was considered as the point of failure. The results of the spalling tests on Series II are shown in Table XI.

Discussion of Results

Some standard for comparison is necessary in order to draw conclusions as to the value of any of the body mixtures for use in the manufacture of electric stove-plates. Shortly after this investigation was started, an effort was made to secure samples of commercial body mixtures to test in the same manner as the mixtures compounded in the laboratory. Four manufacturers in Canada and the United States very kindly supplied unburned samples of their mixtures. These were made into test pieces, burned and subjected to the toughness and thermal-shock tests, and determinations were made of their shrinkage and absorption. The results of these tests showed that the toughest body withstood 26 blows, and the body most resistant to thermal shock withstood 65 immersions, before showing decided cracking. The burning shrinkages varied from 8 to 10 per cent and the absorption from 6 to 15 per cent. As was to be expected the toughest body was not the most resistant to thermal shock, and to increase this property, toughness must be sacrificed. As the resistance to thermal shock is deemed more important, a body representative of the best commercial products may have a shrinkage of from 9 to 12 per cent and an absorption of from 10 to 14 per cent. It would withstand 50 to 65 immersions in the thermal-shock test and have a toughness of from 20 to 24.

Consequently none of the mixtures in Series I is satisfactory for the manufacture of electrical stove-plates. Although the proper burning temperature of every mixture results in shrinkage and absorption well within the figures in the commercial body adopted as standard, and the toughness is in nearly every case higher than the commercial standard, the most important property, resistance to thermal shock, is decidedly deficient. This lack of resistance to thermal shock may be partly due to the high lime content of the talc but it is evident that the proper combination to produce a low coefficient of expansion cannot be expected in mixtures of this nature.

Series II, on the other hand, gave results of the thermal-shock test that are most surprising. All the mixtures containing 30 per cent of magnesium oxide have a very high resistance to sudden temperature change, in several cases withstanding well over 300 immersions. The toughness of No. 7 is well in line with the commercial standard and of Nos. 6 and 8 is sufficiently high to withstand the mechanical shocks to which stove-plates are subjected. The absorptions of these three bodies are low at cone 12, but the shrinkage is unusually high, owing to the high percentage of magnesium oxide used. As this high shrinkage might cause manufacturing difficulties, it was decided to make a further series of mixtures using a high-grade, dead-burned magnesite. This should act in the same manner as a calcine in reducing shrinkage and would be better than a calcine as the relatively low bonding-power makes the reduction of the raw clay-content impracticable.

Plant Tests

At this time an opportunity was offered to make a few tests at the plant of Smith and Stone, Ltd. at Georgetown, Ontario. Mixtures similar to Nos. 6, 7, 8, and 9, were made up in the laboratory and taken to the plant where they were pressed into stove-plates. Some trouble was experienced in pressing the plates and it was evident that these mixtures were lower in bonding strength than the body used at this plant. However, satisfactory plates were obtained, which were dried without trouble and placed in the kilns to be burned. The burning temperature was said to be between cones 10 and 12. The plates when removed from the kiln showed a very high shrinkage, but there was no evidence of excessive warpage or cracking.

The Use of Foreign Magnesites

It was felt that trials of other magnesites as substitutes for the British Columbia hydro-magnesite should be made, and when work was resumed at the laboratories, supplies of caustic-calcined magnesite from Washington, California, Greece, and India, were obtained. Approximate analyses of these were as follows:—

—	Washington	California	Greece	India
	%	%	%	%
Loss on ignition	4·0	3·0	6·6	5·9
CaO	3·0	1·5	0·7	0·2
MgO	85·0	92·5	85·8	88·4

Mixtures proportioned as bodies 6, 7, 8, and 9 were made up, substituting these caustic-calcined magnesites for the hydro-magnesites from British Columbia. Although this involved a considerable amount of work, the results were so similar to those obtained when the British Columbia material was used that it does not seem necessary to give space to tables showing the details. The property of resistance to temperature change was present in the same degree, the toughness was practically the same, and the usual high shrinkage was noted. It was somewhat surprising that the various percentages of lime made no apparent difference in the results of the spalling tests. It may be concluded that the substitution of any of these foreign, caustic-calcined magnesites will not affect any of the properties found to exist in the original body mixtures.

After the completion of the testing of the mixtures referred to above, it was decided to compound a further series of mixtures, Indian caustic-calcined magnesite was used in percentages from 22·5 to 35·0; such a series of mixtures would define the limits of the MgO content that would retain a high resistance to thermal shock. Accordingly, mixtures were prepared in the same manner as previously described and the proportions of Indian magnesite, ball clay and china clay are shown in Table XII. Test pieces were prepared in the same manner and were burned to cone 10 with the same schedule as the previous mixtures. The shrinkage and absorption, and the blows withstood in the toughness test, were as shown in Table XIII. The tests of resistance to temperature change shock were carried on until 100 immersions had been made. None of the test pieces showed any cracks. A study of Table XIII, making allowance for experimental error, shows that a decrease in MgO content decreased both shrinkage and absorption, even with an increase in ball clay content. This tends to prove that the MgO content is responsible for high shrinkage and absorption to a greater extent than the ball clay content. The results of the thermal-shock tests give evidence that the MgO content may be varied between the limits of 22·5 per cent and 35 per cent without seriously impairing this characteristic.

Dead-Burned Magnesite

A relatively pure, dead-burned magnesite was secured with a view to decreasing shrinkage and increasing green bonding power. Such a material was obtained from Degraw Stowe Company, of Cleveland, Ohio, and was substituted for the Indian magnesite in bodies A, B, E, I, J, M, O, and P. These mixtures are referred to as A-1, B-1, E-1, etc. Test pieces were prepared as before and were burned to cone 10 with the same burning curve as previously used. The results showed a relatively low shrinkage and high absorption and another burn was made at cone 12. The results of shrinkage and absorption determinations, and blows required for failure in the toughness test, are shown in Table XIV. Tests of the resistance to thermal shock were run until 100 immersions had been made, at which no failures occurred. Tables XIII and XIV show that the dead-burned magnesite decreased the shrinkage and absorption to a considerable extent, and that no appreciable change was produced in toughness as indicated by the impact test. However, the toughness at cone 12 with the dead-burned magnesite as compared with the cone 12 burn with the British Columbia hydro-magnesite shows a very decided increase.

Green Bonding Strength. The substitution of dead-burned magnesite did not seem to improve the working properties of the mixtures as had been expected. Transverse strength determinations made on bars directly as they were taken from the press showed little difference in this property. It was noted, however, that differences in pressure made a surprising difference in the thickness of the test bar. Consequently, it was decided to determine the green transverse strength of several mixtures at various pressures. The bodies numbered 6, 7 and 8 were of the following compositions:—

Body number	Grecian magnesia	English ball clay	English china clay
6	30	60	10
7	30	50	20
8	30	30	40

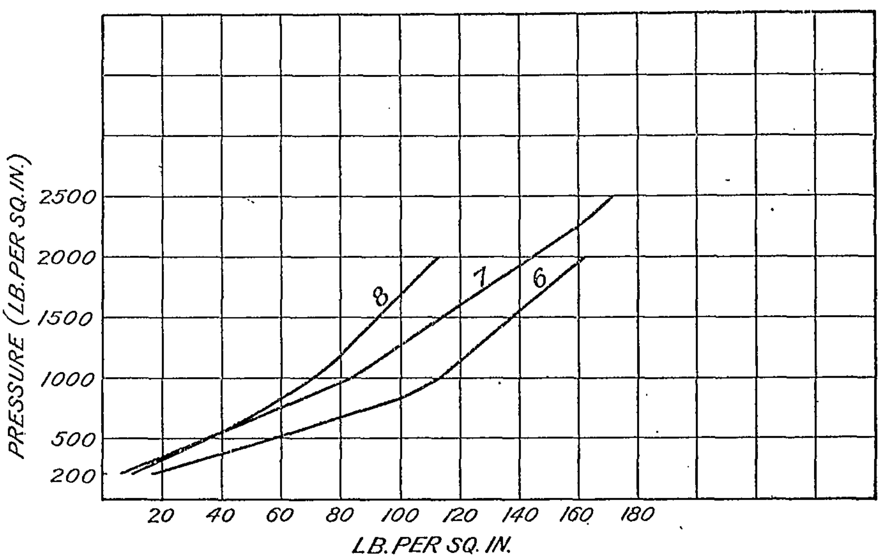

Figure 4. Green transverse strength.

One hundred and twenty transverse bars were pressed from each of these mixtures, 20 of each being pressed with a load of 200, 500, 1,000, 1,500, 2,000, and 2,500 pounds per square inch. Ten bars of each set were broken directly as they came from the press, and the remaining ten were burned to cone 10 and then broken. The results of the tests are graphically represented in Figure 4. When a pressure of 2,500 pounds per square inch was applied to mixture No. 8, decided pressure cracks appeared and no determinations of transverse strength were made on this set of bars. It would appear from these tests that the higher the ball clay content, the higher the green transverse strength at any given pressure and the higher the pressure that might be used without causing defective bars.

CONCLUSION

The results obtained from the various mixtures of calcined magnesites, hydro-magnesites, or dead-burned magnesite with china clay and ball clay, show definitely that the important property of high resistance to thermal shock is consistently developed. In the use of the calcined hydro-magnesite and the various calcined magnesites some practical difficulties might be met because of high burning shrinkage and low, green bonding strength. When a dead-burned magnesite is substituted the burning shrinkage is materially reduced but the green bonding strength is not greatly improved.

Increase in pressure in forming the test bars has a very decided effect and increases the green bonding strength and the burned modulus of rupture. Burning shrinkage was not materially affected by increased pressure, but the small changes noted showed a consistent decrease in shrinkage with increasing pressures.

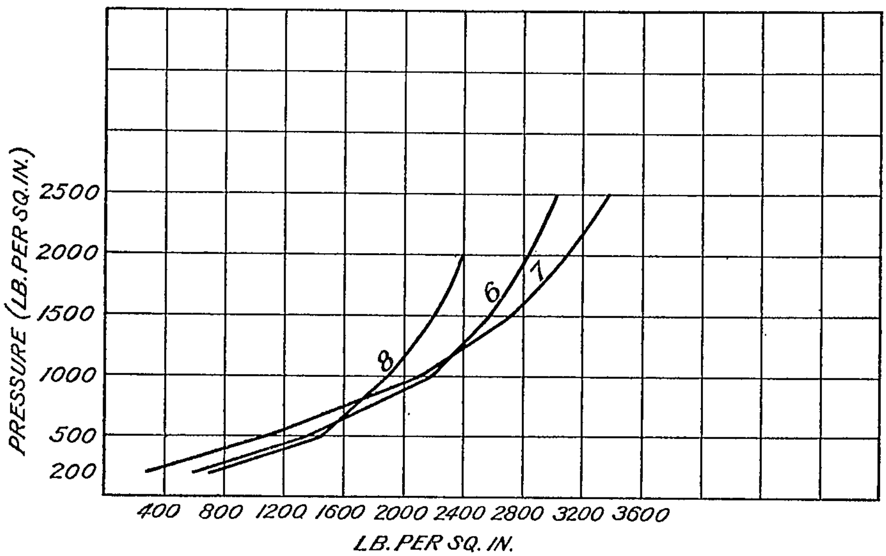

Figure 5. Burned transverse strength.

The most satisfactory method of making use of these bodies in the plant would be to use from 25 to 30 per cent of caustic-calcined or dead-burned magnesite and vary the amounts of ball clay and china clay to suit the requirements of the particular ware being made. If no definite burning shrinkage is to be duplicated, the caustic-calcined magnesite should give good results, with only small losses due to the relatively high shrinkage, if proper care is taken in the processes of manufacture. Where a definite shrinkage must be duplicated, it would be advisable to use dead-burned magnesite, and decrease or increase the ball clay content until the correct shrinkage is obtained. In every case the highest pressure available in the commercial presses will give the best results.

The firing range should be between cones 10 and 12, preferably near the higher limit, in order to obtain the most uniform shrinkage and the best quality of ware.

The results of this investigation show that ware superior to that on the market at the present time could be produced in any plant, after a small amount of experimental work, making use of the data presented. Certainly, laboratory specimens having equal mechanical strength to commercial stove-plates have shown themselves far superior in that very important property of resistance to thermal shock. The unusually high development of this property may very well make these mixtures useful for other types of ware exposed to frequent and sudden temperature change.

TABLE I

Series I

Body No.	Talc	Ball clay	China clay	Body No.	Talc	Ball clay	China clay
1	50	40	10	19	20	40	40
2	50	30	20	20	20	30	50
3	50	20	30	21	20	20	60
4	50	10	40	22	20	10	70
5	40	50	10	23	10	70	20
6	40	40	20	24	10	60	30
7	40	30	30	25	10	50	40
8	40	20	40	26	10	40	50
9	40	10	50	27	10	30	60
10	30	60	10	28	10	20	70
11	30	50	20	29	10	10	80
12	30	40	30	30	....	70	30
13	30	30	40	31	....	60	40
14	30	20	50	32	....	50	50
15	30	10	60	33	....	40	60
16	20	70	10	34	....	30	70
17	20	60	20	35	....	20	80
18	20	50	30				

TABLE II

Series II

Body No.	Calcined hydro-magnesite	Ball clay	China clay	Body No.	Calcined hydro-magnesite	Ball clay	China clay
1	40	50	10	13	20	60	20
2	40	40	20	14	20	50	30
3	40	30	30	15	20	40	40
4	40	20	40	16	20	30	50
5	40	10	50	17	20	20	60
6	30	60	10	18	20	10	70
7	30	50	20	19	10	70	20
8	30	40	30	20	10	60	30
9	30	30	40	21	10	50	40
10	30	20	50	22	10	40	50
11	30	10	60	23	10	30	60
12	20	70	10	24	10	20	70

TABLE III

Fusion Points

Series I		Series I		Series II		Series II	
Body No.	Pyrometric cone equivalent	Body No.	Pyrometric cone equivalent	Body No.	Pyrometric cone equivalent	Body No.	Pyrometric cone equivalent
1	9	20	14	1	17	20	14½
2	15	21	14	2	16	21	15
3	11	22	14	3	14½	22	16
4	8	23	18½	4	17	23	17
5	9½	24	18½	5	18*	24	16
6	10	25	19	5	12		
7	9½	26	17	7	13½		
8	10	27	26	8	13½		
9	10	28	26	9	13½		
10	11	29	26	10	13½		
11	12½	30	32	11	13		
12	11	31	32	12	10		
13	11	32	33	13	11		
14	13	33	33	14	12		
15	14	34	33	15	12		
16	13	35	33	16	12		
17	13			17	14		
18	14			18	14		
19	14			19	12		

*Long range.

TABLE IV

Draw Trial Burn

(Using 3 cylinders of each body for drawing at alternate cones.)

Series I		Series I		Series II		Series II	
Body No.	Cones	Body No.	Cones	Body No.	Cones	Body No.	Cones
1	2, 4, 6	18	4, 6, 8	1	6, 8, 10	18	4, 6, 8
2	6, 8, 10	19	4, 6, 8	2	6, 8, 10	19	4, 6, 8
3	4, 6, 8	20	6, 8, 10	3	6, 8, 10	20	6, 8, 10
4	01, 2, 4	21	6, 8, 10	4	6, 8, 10	21	6, 8, 10
5	2, 4, 6	22	6, 8, 10	5	4, 6, 8	22	8, 10, 12
6	2, 4, 6	23	8, 10, 12	6	4, 6, 8	23	8, 10, 12
7	2, 4, 6	24	8, 10, 12	7	4, 6, 8	24	8, 10, 12
8	2, 4, 6	25	8, 10, 12	8	4, 6, 8		
9	2, 4, 6	26	8, 10, 12	9	4, 6, 8		
10	2, 4, 6	27	8, 10, 12	10	4, 6, 8		
11	2, 4, 6	28	8, 10, 12	11	4, 6, 8		
12	2, 4, 6	29	8, 10, 12	12	2, 4, 6		
13	2, 4, 6	All clay 30	8, 10, 12	13	2, 4, 6		
14	4, 6, 8	31	8, 10, 12	14	4, 6, 8		
15	4, 6, 8	32	8, 10, 12	15	4, 6, 8		
16	4, 6, 8	33	8, 10, 12	16	4, 6, 8		
17	4, 6, 8	34	8, 10, 12	17	4, 6, 8		
		35	8, 10, 12				

24-hour burn, highest cone to be reached 12.

TABLE V

Series I

No.	Cone	Hardness	Per cent absorption	Toughness	Adopted burning range in cones
1	2	Hard	17·0	7	2, 4, 6
	4	"	14·1	7	
	6	Very hard	12·1	13	
2	6	Hard	16·6	10	4, 6, 8
	8	Steel hard	15·9	11	
	10	Vitrified	4·3	15*	
3	4	Hard	18·4	6	4, 6, 8
	6	"	19·8	7	
	8	Very hard	17·9	11	
4	01	Soft	25·4	6	2, 4, 6
	2	Fairly hard	24·3	6	
	4	"	22·7	6	
5	2	Steel hard	12·9	7	2, 4, 6
	4	"	9·7	11	
	6	"	7·6	13	
6	2	Steel hard	14·3	7	2, 4, 6
	4	"	11·7	11	
	6	"	10·4	10	
7	2	Very hard	16·8	8	2, 4, 6
	4	Steel hard	14·9	8	
	6	"	13·0	8	
8	2	Quite hard	19·1	6	6, 8, 10
	4	Very hard	18·1	8	
	6	Steel hard	14·1	8	
9	2	Hard	22·1	5	6, 8, 10
	4	Quite hard	18·4	7	
	6	Very hard	18·8	7	
10	2	Steel hard	9·4	7	2, 4, 6
	4	"	7·3	7	
	6	"	4·8	12	
11	2	Steel hard	12·9	8	2, 4, 6
	4	"	9·7	10	
	6	"	6·6	12	
12	2	Very hard	13·9	6	2, 4, 6
	4	Steel hard	10·3	11	
	6	"	8·0	11	
13	2	Very hard	17·1	8	2, 4, 6
	4	Steel hard	12·8	8	
	6	"	10·4	7	
14	4	Very hard	16·3	7	4, 6, 8
	6	Steel hard	14·3	9	
	8	"	10·4	12	
15	4	Quite hard	16·8	6	4, 6, 8
	6	Very hard	14·8	7	
	8	Steel hard	13·1	10	
16	4	Steel hard	1·8	14	2, 4, 6
	6	"	1·0	14	
	8	"	0·5	12	

* Test piece was not centred and probably had greater toughness.

TABLE V—Continued

Series I—Continued

No.	Cone	Hardness	Per cent absorption	Toughness	Adopted burning range in cones
17	4 6 8	Steel hard " "	3·0 1·3 0·5	12 9† 12	2, 4, 6
18	4 6 8	Steel hard " "	3·2 2·1 0·7	9* 11 13	2, 4, 6
19	4 6 8	Steel hard " "	7·2 3·5 1·4	11 12 14	2, 4, 6
20	4 6 8	Steel hard " "	11·0 5·8 3·8	8 11 14	2, 4, 6
21	6 8 10	Steel hard " "	10·7 4·9 3·5	7 9 3†	4, 6, 8
22	6 8 10	Steel hard " "	12·0 7·7 4·2	8 15 8†	4, 6, 8
23	8 10 12	Steel hard " "	1·2 1·0 0·5	11 7† 11	2, 4, 6
24	8 10 12	Steel hard " "	0·6 .... 0·2	10 † 8	2, 4, 6
25	8 10 12	Steel hard " "	1·7 0·6 0·2	14 7† 12	2, 4, 6
26	8 10 12	Steel hard " "	4·0 0·6 0·5	13 13 12	2, 4, 6
27	8 10 12	Steel hard " "	5·6 2·9 0·9	13 13 15	4, 6, 8
28	8 10 12	Steel hard " "	6·8 3·8 2·4	8 13 12	4, 6, 8
29	8 10 12	Steel hard " "	9·2 6·1 4·6	13 15 16	4, 6, 8
30	8 10 12	Steel hard " "	6·4 4·3 2·5	12 11 14	4, 6, 8
31	8 10 12	Steel hard " "	8·5 6·1 3·7	13 14 12	4, 6, 8

*Test piece was not centred and probably had greater toughness.
†Defective test piece.

TABLE V—Concluded

Series I—Concluded

No.	Cone	Hardness	Per cent absorption	Toughness	Adopted burning range in cones
32	8 10 12	Steel hard...... " ...... "	10·7 7·9 5·8	10 12 13	6, 8, 10
33	8 10 12	Steel hard...... " ...... "	10·8 9·7 6·6	12 12 18	6, 8, 10
34	8 10 12	Steel hard...... " ...... "	14·4 12·2 9·1	9 8 15	6, 8, 10
35	8 10 12	Steel hard...... " ...... "	15·4 14·4 10·8	7 7 12	6, 8, 10

TABLE VI

Series II

No.	Cone	Hardness	Per cent absorption	Toughness	Adopted burning range in cones
1	6 8 10	Soft...... Fairly hard...... "	40·5 29·4 25·2	3 4 4	8, 10, 12
2	6 8 10	Soft...... " ...... "	41·7 35·3 32·7	3 3 3	8, 10, 12
3	6 8 10	Soft...... " ...... "	37·9 35·8 35·2	4 4 2†	8, 10, 12
4	6 8 10	Soft...... " ...... "	40·5 38·0 38·6	3 4 4	8, 10, 12
5	4 6 8	Soft...... " ...... "	39·4 41·3 41·0	3 3 3	8, 10, 12
6	4 6 8	Soft...... Fairly hard...... Hard......	29·6 26·7 25·4	5 6 7	8, 10, 12
7	4 6 8	Fairly hard...... " ...... Hard......	22·2 21·3 21·5	6 6 7	8, 10, 12
8	4 6 8	Soft...... Fairly hard...... "	25·6 24·0 23·2	6 5 5	8, 10, 12
9	4 6 8	Soft...... Fairly hard...... Hard......	28·3 25·8 23·6	5 6 6	8, 10, 12

†Defective test piece.

TABLE VI—Concluded

Series II—Concluded

No.	Cone	Hardness	Per cent absorption	Toughness	Adopted burning range in cones
10	4 6 8	Soft Fairly hard Hard	28·6 28·3 25·5	5 6 5	8, 10, 12
11	4 6 8	Soft Fairly hard "	31·5 30·0 28·1	6 6 6	8, 10, 12
12	2 4 6	Very hard Steel hard "	16·0 13·7 11·8	7 7 7	2, 4, 6
13	2 4 6	Quite hard Very hard Steel hard	20·4 16·2 12·3	7 6 8	2, 4, 6
14	4 6 8	Quite hard Very hard Steel hard	17·8 13·3 12·6	7 6 8	4, 6, 8
15	4 6 8	Hard Quite hard Steel hard	19·0 16·2 14·2	6 6 7	6, 8, 10
16	4 6 8	Quite hard Very hard Steel hard	20·9 18·6 14·9	6 5 7	6, 8, 10
17	4 6 8	Hard " Very hard	22·1 22·0 17·0	6 4† 6	6, 8, 10
18	4 6 8	Hard " Quite hard	24·1 22·8 22·1	6 6 6	8, 10, 12
19	4 6 8	Steel hard " "	7·5 6·5 5·7	7 9 8	2, 4, 6
20	6 8 10	Steel hard " "	8·3 6·2 5·8	9 6 10†	4, 6, 8
21	6 8 10	Steel hard " "	9·6 6·6 5·7	8 10 11	4, 6, 8
22	8 10 12	Steel hard " "	6·8 6·8 4·4	10 8 11	4, 6, 8
23	8 10 12	Steel hard " "	8·5 7·9 5·5	8 8 11	4, 6, 8
24	8 10 12	Steel hard " "	11·1 9·8 8·7	8 6 10	4, 6, 8

†Defective test piece.

TABLE VII

Toughness

Series I

No.	Cone	Average toughness	No.	Cone	Average toughness
1....................	2	22	19..................	2	23
	4	28		4	25
	6	28		6	30
2....................	4	20	20..................	2	23
	6	27		4	24
	8	29		6	33
3....................	4	18	21..................	4	23
	6	27		6	25
	8	29		8	31
4....................	2	17	22..................	4	19
	4	21		6	25
	6	20		8	33
5....................	2	21	23..................	2	20
	4	29		4	22
	6	29		6	25
6....................	2	22	24..................	2	22
	4	29		4	28
	6	30		6	35
7....................	2	19	25..................	2	20
	4	26		4	23
	6	28		6	26
8....................	6	31	26..................	2	18
	8	28		4	24
	10	....		6	37
9....................	6	19	27..................	4	24
	8	24		6	30
	10	32		8	31
10....................	2	21	28..................	4	19
	4	34		6	26
	6	34		8	30
11....................	2	22	29..................	4	18
	4	35		6	23
	6	35		8	33
12....................	2	22	30..................	4	35
	4	31		6	34
	6	34		8	33
13....................	2	18	31..................	4	27
	4	25		6	29
	6	25		8	35
14....................	4	20	32..................	6	29
	6	25		8	34
	8	29		10	41
15....................	4	16	33..................	6	27
	6	23		8	32
	8	28		10	30
16....................	2	23	34..................	6	24
	4	28		8	26
	6	34		10	30
17....................	2	23	35..................	6	21
	4	25		8	26
	6	34		10	26
18....................	2	22			
	4	30			
	6	35			

TABLE VIII

Toughness

Series II

No.	Cone	Average toughness	No.	Cone	Average toughness
1	8	7	13	2	11
	10	8		4	12
	12	25		6	18
2	8	7	14	4	13
	10	6		6	16
	12	19		8	19
3	8	7	15	6	14
	10	6		8	18
	12	19		10	19
4	8	7	16	6	14
	10	6		8	17
	12	17		10	21
5	8	7	17	6	16
	10	6		8	18
	12	15		10	20
6	8	12	18	8	12
	10	13		10	18
	12	16		12	21
7	8	14	19	2	20
	10	13		4	24
	12	22		6	29
8	8	13	20	4	25
	10	13		6	29
	12	17		8	35
9	8	11	21	4	21
	10	11		6	31
	12	10		8	38
10	8	14	22	4	22
	10	12		6	32
	12	10		8	38
11	8	12	23	4	17
	10	13		6	25
	12	9		8	31
12	2	14	24	4	15
	4	14		6	18
	6	16		8	25

TABLE IX

Shrinkage and Absorption

Series I

No.	Cone	Shrinkage, per cent	Absorption, per cent
1...........	2	2·95	16·0
	4	3·63	12·6
	6	3·31	11·9
2...........	4	2·94	17·5
	6	2·94	15·3
	8	3·02	15·8
3...........	4	3·08	20·8
	6	3·01	20·6
	8	3·01	18·2
4...........	2	1·80	25·6
	4	2·39	22·4
	6	2·46	22·6
5...........	2	4·25	15·0
	4	5·39	9·2
	6	4·28	8·6
6...........	2	3·88	17·0
	4	3·21	10·2
	6	5·01	10·8
7...........	2	3·41	18·6
	4	4·66	13·6
	6	4·74	13·1
8...........	6	4·26	15·7
	8	4·20	14·8
	10	5·66	—
9...........	6	3·92	19·9
	8	4·18	17·3
	10	5·11	5·6
10...........	2	6·60	13·3
	4	9·94	5·5
	6	8·60	5·4
11...........	2	5·93	15·4
	4	8·87	6·6
	6	8·87	5·6
12...........	2	5·66	17·5
	4	8·19	9·0
	6	7·93	8·4
13...........	2	5·20	20·3
	4	6·87	12·6
	6	7·80	11·3
14...........	4	5·90	16·6
	6	6·50	14·9
	8	7·63	10·5
15...........	4	5·33	20·7
	6	5·89	17·1
	8	6·08	12·8
16...........	2	9·26	8·3
	4	10·95	2·1
	6	11·15	0·8
17...........	2	9·82	10·2
	4	11·11	3·4
	6	11·71	1·3
18...........	2	8·42	12·2
	4	10·37	6·7
	6	11·00	2·1
19...........	2	7·20	15·1
	4	9·59	9·1
	6	10·92	5·2
20...........	2	6·34	17·5
	4	8·54	13·0
	6	10·02	8·5
21...........	4	7·73	15·0
	6	9·56	11·4
	8	10·49	9·2
22...........	4	7·04	17·8
	6	9·24	12·5
	8	9·91	11·1
23...........	2	8·63	13·2
	4	11·26	6·8
	6	12·49	17·2
24...........	2	8·43	14·5
	4	10·79	8·8
	6	12·83	1·8
25...........	2	7·69	17·3
	4	10·51	9·9
	6	12·48	2·9
26...........	2	6·76	13·4
	4	9·42	12·5
	6	11·25	6·5
27...........	4	8·56	13·7
	6	11·32	10·1
	8	12·19	5·5
28...........	4	7·37	17·7
	6	9·45	13·2
	8	11·52	8·6
29...........	4	5·96	21·2
	6	8·21	16·7
	8	16·36	10·8
30...........	4	10·44	11·3
	6	11·49	9·7
	8	12·55	5·8
31...........	4	9·78	12·8
	6	11·00	10·1
	8	12·39	8·4
32...........	6	10·07	12·4
	8	11·35	9·5
	10	12·89	4·8
33...........	6	9·68	14·1
	8	10·74	11·5
	10	12·67	7·4
34...........	6	8·51	16·4
	8	9·64	13·0
	10	12·05	9·1
35...........	6	7·98	11·5
	8	8·97	14·9
	10	11·29	11·3

TABLE X

Shrinkage and Absorption

Series II

No.	Cone	Shrinkage, per cent	Absorption, per cent	No.	Cone	Shrinkage, per cent	Absorption, per cent
1...........	8	13·11	32·6	13..........	2	9·37	29·6
	10	15·77	25·7		4	15·15	19·0
	12	22·52	7·3		6	15·82	13·9
2...........	8	10·34	33·6	14..........	4	12·34	20·8
	10	10·07	34·3		6	14·81	14·5
	12	18·47	10·5		8	15·00	12·6
3...........	8	3·52	33·6	15..........	6	14·33	16·8
	10	7·92	33·4		8	14·74	13·8
	12	16·52	9·7		10	14·26	11·1
4...........	8	8·68	37·1	16..........	6	13·00	20·3
	10	8·54	30·7		8	14·26	15·0
	12	15·36	13·4		10	13·81	12·3
5...........	8	8·28	37·8	17..........	6	12·52	21·3
	10	7·88	39·5		8	14·44	14·8
	12	8·02	18·4		10	13·85	14·6
6...........	8	11·80	26·2	18..........	8	—	18·0
	10	11·61	24·5		10	13·85	18·0
	12	20·50	2·3		12	13·05	13·7
7...........	8	12·41	21·0	19..........	2	13·58	17·4
	10	12·42	20·2		4	17·44	10·5
	12	19·70	1·8		6	18·37	6·6
8...........	8	11·82	22·2	20..........	4	15·30	12·8
	10	11·82	21·0		6	16·74	8·6
	12	19·49	1·5		8	17·15	6·0
9...........	8	11·87	23·4	21..........	4	14·72	14·5
	10	11·68	20·0		6	16·75	10·0
	12	15·95	1·3		8	17·35	6·8
10...........	8	11·97	23·6	22..........	4	10·50	16·4
	10	10·93	25·4		6	16·15	10·0
	12	11·36	18·3		8	17·43	7·3
11...........	8	10·57	26·0	23..........	4	9·38	17·8
	10	9·77	27·4		6	15·04	13·6
	12	9·32	21·0		8	16·42	9·4
12...........	2	11·53	23·1	24..........	4	8·86	21·7
	4	15·32	15·2		6	—	20·1
	6	15·80	12·1		8	16·43	11·7

TABLE XI

Results of Thermal Shock Tests

Series I

The only bodies in this series that withstood more than 3 or 4 immersions were 2, 3, 8, and 9. Nos. 2 and 3 were burned to cones 4, 6, and 8. They both withstood 2 immersions at cone 4, and 5 at cone 6, and about 18 immersions at cone 8. No. 2 is a little more resistant than No. 3.

Nos. 8 and 9 were burned to cones 6, 8, and 10. No. 8 withstood 3 immersions at cone 6, 21 at cone 8, and 8 at cone 10. No. 9 withstood 2 immersions at cone 6, 30 at cone 8, and 16 at cone 10.

Series II

Body No.	Cone	Total immersions	Body No.	Cone	Total immersions
1	8	10	13	2	3
	10	2		4	2
	12	1		6	3
2	8	13	14	4	3
	10	20		6	2
	12	1		8	3
3	8	85	15	6	2
	10	34		8	5
	12	1		10	32
4	8	24	16	6	2
	10	16		8	2
	12	1		10	37
5	8	67	17	6	2
	10	185		8	2
	12	1		10	35
6	8	23	18	8	2
	10	221		10	4
	12	338		12	230
7	8	13	19	2	2
	10	159		4	2
	12	339		6	2
8	8	6	20	4	2
	10	190		6	2
	12	253		8	2
9	8	9	21	4	2
	10	52		6	2
	12	332		8	2
10	8	10	22	4	2
	10	12		6	2
	12	200		8	2
11	8	6	23	4	2
	10	28		6	2
	12	64		8	2
12	2	2	24	4	2
	4	2		6	2
	6	2		8	2

TABLE XII

Body No.	Calcined Indian magnesite	English ball clay	English china clay	Body No.	Calcined Indian magnesite	English ball clay	English china clay
A........	35·0	55·0	10·0	I........	35·0	45·0	20·0
B........	32·5	57·5	10·0	J........	32·5	47·5	20·0
C........	30·0	60·0	10·0	K........	30·0	50·0	20·0
D........	27·5	62·5	10·0	L........	27·5	52·5	20·0
E........	25·0	65·0	10·0	M........	25·0	55·0	20·0
F........	32·5	57·5	15·0	N........	22·5	37·5	40·0
G........	30·0	55·0	15·0	O........	22·5	27·5	50·0
H........	27·5	52·5	15·0	P........	22·5	17·5	60·0

TABLE XIII

Cone 10

No.	Shrinkage, per cent	Absorption, per cent	Toughness	No.	Shrinkage, per cent	Absorption, per cent	Toughness
A........	17·2	22·2	12	L........	13·0	27·0	13
B........	14·2	23·7	14	M........	13·8	16·3	18
C........	12·4	23·8	13	N........	12·8	17·1	15
D........	12·8	21·6	14	O........	13·8	17·4	13
E........	15·0	14·8	17	P........	13·5	17·9	14
F........	13·3	14·5	16	Q........	13·9	12·1	17
G........	13·7	21·0	14	R........	15·5	11·4	17
H........	12·8	21·5	15	S........	14·0	13·1	17
I........	12·6	23·4	9	T........	17·4	4·7	18
J........	12·4	25·8	12	U........	15·1	11·9	19
K........	12·0	23·6	14	V........	15·4	7·4	17

Thermal-shock test all over 100 immersions.

TABLE XIV

Cone 10

No.	Shrinkage, per cent	Absorption, per cent	Toughness	No.	Shrinkage, per cent	Absorption, per cent	Toughness
A—1.....	10·1	14·4	14	J—1......	8·7	12·9	17
B—1.....	10·9	10·3	18	M—1....	13·7	5·2	18
E—1.....	14·7	5·7	20	O—1.....	12·7	9·6	16
I—1.....	9·0	14·5	13	P—1.....	11·2	12·2	15

Thermal-shock test all over 100 immersions.

Cone 12

No.	Shrinkage, per cent	Absorption, per cent	Toughness	No.	Shrinkage, per cent	Absorption, per cent	Toughness
A—1.....	11·3	10·6	14	J—1.....	9·9	12·4	18
B—1.....	11·8	8·8	20	M—1....	14·5	2·0	32
E—1.....	15·6	1·8	34	O—1.....	14·6	4·4	25
I—1.....	10·3	10·9	17	P—1.....	13·7	7·5	23

Thermal-shock test all over 100 immersions.

II

COLOUR CONTROL OF BRICK

L. P. Collin

Many improvements and diversifications in colour and texture of building brick have been developed during the past twenty-five or thirty years. The first radical changes from the plain red or buff colours, and the comparatively smooth, uniform textures are still within the memory of most brick manufacturers of today. Methods of firing the kilns were altered, the setting of the brick in the kiln was changed, and a wide range of variegated and plain colours resulted. Not only were changes made in colour, but important changes were also made in the texture of the face of the brick, although the various textures produced are more or less display bases for imparting added effectiveness to the colours themselves.

At the same time that these changes were taking place in colours and textures there was a demand for light-coloured, smooth-textured brick that would produce an effect similar to that of limestone. Large office buildings in the more important urban centres, in particular, came to be built more and more of various shades of light-coloured brick, popularly known as grey brick. These colours were produced by adding chemicals to the raw material of the brick.

However, even with the many colours, and the interesting and novel textures now being produced, there is a demand for a still wider range. Within the last few years many large buildings, especially in the United States, have been constructed with glazed brick, and demand for this type is very likely to develop in Canada. What may come next, no one can say, but it seems certain that the demand for new effects will result in continuing changes in the appearance of clay and shale building-units.

Colour depends primarily upon the raw materials used. The natural colour may, however, be modified or even completely changed, by methods of burning, by additions to the raw material, or by surface applications. As there are several variations and combinations of these methods of colour control, a brief discussion of each follows:—

Coloration by "Flashing". Clays that naturally burn red develop the clearest red when burned under oxidizing conditions. If, however, near the finish of the burn, the atmosphere is made reducing, by decreasing the quantity of air allowed to enter the kiln, the iron compounds are partly reduced, which results in the production of a wide range of colours including reds, browns, and blacks. Normally buff-burning materials, especially those containing considerable lime, may be flashed, as this reduction is termed, and produce yellows, browns, and greens. The manipulation of atmospheric conditions to produce a desired range of colours generally requires considerable experience with each different raw material and in many cases experiments over a period of years are necessary to establish colour ranges that may be duplicated at will. Nevertheless, this method of obtaining and controlling colours is the cheapest of any, and produces an extremely wide range of plain and variegated colours.

Coloration by Chemicals in Kiln Atmosphere. Many pleasing effects can be obtained by the use of various chemicals volatilized in the fireboxes, at or near the end of burning. The popular salt-glazed brick are made by throwing sodium chloride (common salt), in the fireboxes at the completion of firing. Not every clay or shale will take a salt glaze, and the art of salt glazing is not so simple as it would appear. In the case of building brick, salt glazes are usually applied to buff-burning materials with a resultant range of glaze colours from light yellow to brown. Zinc is often used to produce green colours, and manganese for brown or black. The charges are always thrown into the fireboxes near the end of the burn.

Coloration by Chemicals Mixed with Raw Materials. Lime, generally in the form of marl or ground limestone, is often mixed with clays and shales to produce a buff brick from a normally red-burning material. Iron oxide is sometimes used to improve the red colour. Manganese dioxide mixed with red-burning clays or shales gives desirable browns and blacks, or when mixed with certain buff-burning materials, produces the popular grey shades already referred to.

Coloration by Spraying Soluble Salts of Metals on Brick. In some cases soluble salts of the metallic colouring agents are sprayed on the surfaces of green or dried bricks. When these brick are burned, the salts react with the alumina and silica in the clays and form insoluble, coloured compounds.

Coloration by the Application of Vitreous Coloured Particles. Granular, coloured glass is sometimes applied to the surface of brick by pressure, such as in sand moulding, rolling into the clay column, or by a process similar to sand blasting. During the firing, these glasses melt and form a vitrified surface on the face of the brick, in variegated or plain colours, depending on the glasses used.

Coloration by Veneer Coating. In some cases a clay veneer of considerable thickness is applied by the use of an auxiliary auger working in synchrony with the usual auger of the brick machine. This process makes possible the production of a range of colours by using for the veneer various clays that burn to different colours. This process may also be used with clays to which colouring agents have been added. In order to ensure a a suitable bond between the bulk of the brick and the veneered surfaces, the clays used should have similar physical properties.

Coloration by Slip Coatings. The coloration of brick by the application of glazes, enamels, and other slips has certain advantages. Extremely wide colour ranges can be produced and an impervious surface can be obtained, which will remain cleaner than a porous surface. There are obvious manufacturing and shipping difficulties which must be contended with. However, glazed brick are becoming very popular, and manufacturing control and shipping methods are being constantly improved.

PRODUCTION OF GREY BRICK IN CANADA

The Ceramics Division has received many requests for information on the possibility of producing grey brick from the brick clays and shales of eastern Canada. As the most pressing requests were from Ontario and Quebec, raw materials from these provinces were used in the first experiments. Two of the previously outlined methods of colour development were used, namely, mixing chemicals with the raw materials and applying slip to the surface of the brick.

While these experiments were under way, a request was received from the Maritime Provinces for experimental work on colour control and development. All of this work is covered in the following sections:

Additions of Limestone Dust and Manganese Dioxide

Grey brick are generally produced by adding small percentages of manganese dioxide to buff-burning, low-grade fireclays. There are only a few good quality, buff-burning, brick clays in Ontario and Quebec, and these, having a very low softening point, are quite different from those from which grey brick are ordinarily made. The clays and shales used in this experimental work were representative of the Ontario and Quebec buff-burning brick materials and were obtained from the Don Valley plant of the Toronto Brick Company, Limited, and the Citadel Brick, Limited, Quebec. The manganese dioxide was the ordinary commercial grade.

It was found advisable to add limestone dust to the Canadian materials used, so that the bleaching action of the lime might produce a lighter background than is natural with these materials. The limestone dust is a product of a high-calcium stone, containing over 95 per cent calcium carbonate, which occurs at Deschambault, Quebec. A screen analysis of this stone dust was as follows:

Screen mesh	Limestone dust, per cent
On 65	4·40
" 100	51·20
" 150	11·55
" 200	18·90
" 270	10·10
Through 270	3·40

Mixtures were made containing from one-half to 4 per cent of manganese dioxide and from 2 to 12 per cent of limestone dust. Various grain sizes of manganese dioxide were used, ranging from the very fine, air-floated material to 20-mesh grains. Briquettes made from these mixtures were burned in both oxidizing and reducing atmospheres. Satisfactory grey shades were obtained in the oxidizing burns with the materials from both plants. Following this laboratory work, plant tests were made at both the Don Valley and Citadel Brick works. The results were not the same as were obtained in the laboratory kilns. However, it would seem that a satisfactory colour could be obtained in commercial kilns, but not economically. About 4 per cent magnanese dioxide and

8 per cent limestone dust would be required and this would make the cost very high. In addition to this, the brick made with such a large percentage of limestone dust would not be so hard or strong as the imported grey brick.

The above work has shown that it is not economically feasible to produce a grey brick from these materials, with additions of manganese dioxide and limestone dust, capable of competing with the imported product.

Several imported grey brick were examined under the microscope, and in every case it was found that their structure was quite vitreous. It is probable that the light-reflecting properties produced by this vitreous structure are of great importance in imparting a pleasing grey effect. It is known that the brick clays and shales of Ontario and Quebec cannot be safely burned to a vitreous condition on account of their short vitrification range. Although manganese dioxide may not have the same reaction at the burning temperature of the Ontario and Quebec brick materials as it does at the higher temperatures to which the low-grade fireclay brick are burned, the lack of vitreous structure is responsible for the unsatisfactory results. It would seem that if grey brick are to be made from these raw materials it will be only through some process quite different from that employed by the manufacturers of the imported brick.

The Use of Slip for Producing Grey Brick

Considerable work was carried on in the laboratory and at the plant of the Citadel Brick, Limited, to determine if it would be feasible to produce satisfactory grey brick by the use of a slip covering. The experimental work in the laboratories consisted of preparing slips, from various mixtures of fireclay, manganese, and fluxes, and applying them to dry briquettes and burning these to the maturing temperature of the Citadel shale. White lead was found to be the most suitable flux and several good grey coloured slips were obtained.

Following this, experimental work was carried on at the plant of the Citadel Brick, Limited, in Quebec. In all, some seventy slips were prepared and applied to the surface of dry brick by means of a spray-gun. Sixteen brick were sprayed with each slip, four of which were placed in the top-fired continuous kiln, and twelve in the round, down-draught, intermittent kilns. The four brick in the continuous kiln were placed near the centre of the ware, two being faced on edge and two on flat. The twelve brick for the round, down-draught kilns were placed in three positions, top, centre, and bottom, in each case with two faced on edge and two on flat. The results obtained with the slips consisting of fireclay, white lead, and manganese dioxide were not satisfactory. The slips in the continuous kiln were not matured, as the temperature is lower than that in the intermittent kilns. In addition to this, the colours were darker than was desired, although similar slips gave satisactory results in the laboratory. The results in the intermittent kilns were still more unsatisfactory, as in these kilns the burns were completed with a strongly reducing atmosphere which caused the colours to be very dark, mostly browns and in some cases almost black.

The next step was to prepare slips containing china clay, ball clay, white lead, and manganese dioxide. These slips were applied in the same manner, and the sprayed brick were placed in similar positions in the kilns. The results were more satisfactory than those obtained with the fireclays. There were several very good greys. The best, both in reducing and oxidizing atmospheres, was composed of the following:

Ball clay	50
China clay	28
White lead	12
Manganese dioxide, 60–80 mesh	10

Although the colours produced with this slip were good, vitrification was not carried sufficiently far and a higher percentage of flux should be used.

Due to the probability of high losses in handling and shipping, there was not sufficient confidence in the success of producing grey brick that would be acceptable to the market, by the application of slips, to warrant this process being tried on a commercial scale.

Production of Light Buff and Grey Brick in the Maritime Provinces

A request was received from a manufacturer in the Maritimes for experimental work to produce golden-buff and grey brick to compete with brick being imported from the United States. The first step in this work was to determine what clays in the Maritime Provinces were of such a nature that they might be used to produce the colours desired. It was decided that a clay occurring at Shubenacadie, Nova Scotia, which is quite refractory and which burns almost white in colour, and clays of a semi-refractory quality occurring at Middle Musquodoboit, Nova Scotia, were the most promising materials to use. The plant which would use these clays is situated in New Brunswick and the long freight haul would make them high in cost. Therefore, a buff-burning undershale obtained from one of the mines of the Rothwell Coal Company, of Minto, New Brunswick, which is near the plant, was used with the Nova Scotia clays.

The Shubenacadie clay produced very good, light buffs when mixed with 70 per cent or less of the Rothwell buff shale, and very good greys were produced from these mixtures by adding 1 per cent of air-floated manganese dioxide. However, upon examining the deposits of this buff shale in the mine, it was found that the supply was limited and that great variations in colour occurred in the different parts of the mine.

It was then decided to work with mixtures of the red-burning overshale, from this mine, which was then being used at Chipman, New Brunswick, for the manufacture of red face brick. These experiments showed that good buffs and greys could be produced by using approximately one-third of the red-burning overshale and two-thirds of the Shubenacadie clay.

Material from Middle Musquodoboit did not give as satisfactory results. The clays, for the most part, burned to a light red in colour, and would not be suitable for producing the brick desired. As it would not be economical to use the small portion of the suitable light-burning material, no further work was conducted with the clays of this locality.

The next step was to duplicate the results of the laboratory work in commercial production. Before doing this, full-sized, dry-pressed brick were made and burned in the laboratory from the Shubenacadie clay and from mixtures of this clay and the Rothwell shale. The following batches were used.:

1. 50 per cent Rothwell overshale
   50 per cent Shubenacadie clay
   Additions—
   0·5 per cent 200-mesh manganese dioxide
   0·5 per cent 40- to 80-mesh manganese dioxide

2. 30 per cent Rothwell overshale
   70 per cent Shubenacadie clay
   Additions—
   0·5 per cent 200-mesh manganese dioxide
   0·5 per cent 40- to 60-mesh manganese dioxide

3. 70 per cent Rothwell overshale
   30 per cent Shubenacadie clay
   Additions
   0·5 per cent 200-mesh manganese dioxide
   0·5 per cent 20- to 40-mesh manganese dioxide

4. 100 per cent Shubenacadie clay
   Additions—
   1 per cent 200-mesh manganese dioxide

5. 100 per cent Shubenacadie clay
   Additions—
   1 per cent 200-mesh manganese dioxide
   0·5 per cent 40- to 60-mesh manganese dioxide

6. 100 per cent Shubenacadie clay
   Additions—
   0·5 per cent 200-mesh manganese dioxide
   1 per cent 40- to 60-mesh manganese dioxide

7. 100 per cent Shubenacadie clay
   Additions—
   1 per cent 40- to 60-mesh manganese dioxide

8. 100 per cent Shubenacadie clay
   Additions—
   0·5 per cent 40- to 60-mesh manganese dioxide
   0·5 per cent 20- to 40-mesh manganese dioxide

The brick, after being pressed, were set, faced, in one of the laboratory kilns, and were burned to cone 8.

The bricks made from No. 1 mixture were a pleasing brownish buff in colour and showed a considerable number of manganese specks.

No. 2 mixture was lighter in colour, being a buff very similar to some of the darker greys made in the United States.

No. 3 mixture was slightly darker than No. 1, but the colour, with the effect of the manganese specks, was very pleasing.

No. 4 was a very good light limestone grey.

No. 5 was a very pleasing, medium dark grey, with a considerable number of manganese specks.

No. 6 was a good grey and, combined with the effect of the manganese specks, gave a very pleasing appearance.

Nos. 7 and 8 were almost white, with black specks, and the only difference was in the relative size of these specks.

These results were so satisfactory that it was thought desirable to erect a panel from each set of bricks, and to take these panels to the Maritime Provinces to show the manufacturers and architects what could be produced by the use of these materials.

The appearance and quality of these brick were highly satisfactory to the architects who saw them. A Maritime manufacturer was so impressed that, following confirmatory tests carried out in the factory, he began to manufacture some of the buff shades, and intends to produce a complete line of buff and grey brick that can compete with any such brick imported from the United States.

Experimental Work on Salt Glazing

At the request, and with the co-operation of L. E. Shaw, Limited, laboratory experiments were made to determine the possibility of producing salt-glazed brick from the Shubenacadie clay, and from mixtures of this clay and the red-burning overshale obtained from the Rothwell mine at Minto, New Brunswick.

As the larger of our laboratory kilns are gas fired, it was not practical to follow the usual practice of volatilizing the salt in the fireboxes. The most suitable method of introducing the salt fumes into the kiln atmosphere was found to be placing the salt into the kiln chamber where volatilization would take place. Accordingly the bag walls were widened in one of our rectangular kilns to form a table upon which the salt might be spread, as uniformly as possible, by means of a small shovel with a long handle. This scheme worked very well, but the next problem was to hold the salt fumes within the kiln for a sufficient length of time, without obtaining reducing conditions that would darken the colour of the brick and glaze. Several methods of setting the brick were tried and finally one was found which was satisfactory.

Full-sized dry-press brick were made from the various mixtures and these were burned to cone 8. From three to five saltings were given, the amount of glaze formed on the brick being judged by draw trials.

The mixtures of clay with the Rothwell shale were not suitable for salt glazing as, at the temperature required to obtain a dense body, the shale caused pimpling to develop to a considerable extent. In addition to this the colours obtained with the mixture were darker than desired. It was found that the Shubenacadie clay, without addition of any other material, could be satisfactorily covered with a smooth, bright salt-glaze having the desired range of colours. From these laboratory experiments it would appear that a marketable salt-glaze brick could be commercially produced from the Shubenacadie clay.

III

ROOFING-TILE CLAYS AND SHALES OF EASTERN CANADA

J. F. McMahon

Considerable interest has been shown of recent years in the clays and shales of Canada concerning their suitabliity for the manufacture of roofing-tile, and many inquiries on this subject have been received by the department. The object of this report is to furnish information on those clays and shales in eastern Canada that may be regarded as suitable for the manufacture of roofing-tile.

As the result of a specific enquiry for information about clays or shales, occurring on the Atlantic seaboard, suitable for the manufacture of roofing-tile, a number of the more promising deposits in the Maritime Provinces and in eastern Quebec were visited and sampled. These samples were later subjected to very full tests. In view of other inquiries regarding roofing-tile materials it was decided to make a compilation of the results from the above samples, together with the information published in reports and accumulated by our division on the clays and shales of eastern Canada.

Records show that clay roofing-tile were manufactured as early as 1000 B.C., and that there are many countries where the industry today is a thriving one. One is naturally curious why this ancient industry is so poorly represented on the American continent, and particularly so in Canada.

The reasons advanced for this are as follows:

1. The greater availability of other kinds of roofing materials placed the clay tile at a disadvantage as regards initial cost.

The clay roofing-tile has always encountered strong competition in the United States and Canada, from the time when the wood shingle was very cheap until the present time when the market is well supplied with inexpensive roofings of various kinds, including wood, asphaltum, metal, slate, and composition varieties. There has been, therefore, no pressing demand for the clay roofing-tile and consequently no real incentive to promote this industry. However, architects who desired to add distinction to their work by the choice of different roofing materials, have chosen clay roofing-tiles for some of the finest residences and public buildings, on account of the individuality and attractiveness which they possess owing to their natural diversity of colours and shades. As a consequence it is not uncommon to see the cheaper dwelling roofed with material imitating in form and colour the clay tile.

2. The lack of knowledge of the pioneers of this country resulted in the choice of inferior raw materials with consequent losses and financial failures.

A person, who has been engaged in the industry elsewhere, might readily attempt to start a similar industry on this side of the water, but having in the old world become acquainted perhaps with only a single phase of this industry, would be apt to believe that all clays were economically suited for the manufacture of good roofing-tile. Worcester[1] found evidence of such beliefs in the results of tests run on materials at one time or another used for the production of clay roofing-tile in the United States. This criticism might apply equally to the few early attempts in Canada. The quality and cheapness demanded of the article did not permit of slow development. The materials chosen were not the best and those in charge probably lacked the technical skill and knowledge to solve the problems presented by highly plastic and short-ranged materials. One failure in an industry may not prevent the growth of that industry, but psychologically the effect would be bad.

3. Arguments against the clay roofing-tile resulted in a prejudice against the product.

Prejudices against clay roofing-tile exist, from which the general public will need to be freed. In the course of conversation, it is not uncommon to hear remarks similar to the following: "Clay roofing-tile are too heavy for the average home"; "Clay tile will not withstand the temperature changes of our climate"; "Clay roofing-tile are too expensive". Few, if any, Canadian homes are not built ruggedly enough to carry clay roofing-tile, and the many fine residences in Canada topped with clay roofing-tile, disprove the idea of their unsuitability for this climate. The cost of roofing-tile at present may be relatively high, but it is believed that clay roofing-tile could be made at a price sufficiently attractive to interest the small-home builder.

The history of the roofing-tile industry in the United States illustrates better the trend of development, which is in a much more advanced stage than in Canada. The figures below give an idea of the status of the industry there.

State	Number of Plants		State	Number of Plants	
	1910	1929		1910	1929
California	4	29	New Mexico	0	1
Colorado	0	2	New York	2	0
Florida	0	1	Ohio	4	2
Georgia	1	1	Oregon	0	1
Illinois	1	0	Pennsylvania	0	2
Indiana	0	1	Tennessee	0	2
Kansas	1	2	Texas	0	2
Kentucky	1	2	Washington	0	4
Michigan	1	0	W. Virginia	2	1
Missouri	1	1			
			Total	18	54*

*Although in 1929 54 plants are recorded, 30 plants produced 86·8 per cent of the total value and quantity of clay roofing-tile for that year, the other plants being engaged in the manufacture of other products.

Total Production in the United States

—	Squares	Value	—	Squares	Value
		$			$
1925	289,956	5,155,301	1929	370,771	3,943,847
1926	408,724	7,015,775	1930	297,429	3,899,885
1927	368,451	5,348,750	1931	286,000	3,139,000
1928	351,360	4,764,208			

[1] Geological Survey of Ohio, Fourth Series, Bulletin 11, Manufacture of Roofing-Tile, Worcester-Orton, 1910.

At present Canada has two plants engaged in the production of roofing-tile. One has been in operation since 1910 and the other has recently been organized. Statistics on this commodity in Canada do not afford a very complete picture of the industry.

Roofing-Tile Produced in Canada

—	Number of Tile	Value	—	Number of Tile	Value
		$			$
1924	7,377	917	1928	72,930	6,435
1925	78,479	6,323	1929	35,075	4,628
1926	17,018	1,562	1930	3,056	356
1927	2,000	140	1931	6,935	720

CLASSIFICATION OF ROOFING-TILE

- By manufacturing methods
  - Hand
  - Machine
    - Stiff plastic
    - Plastic
    - Dry-press
- By porosity
  - Porous
  - Vitrified
- By shape
  - Shingle
  - Spanish
- By finish
  - Plain
  - Sanded
  - Glazed
  - Engobed

The above classifications may be linked up making a lengthy list of varieties, therefore in the selection of raw material it is necessary to have in mind the variety that it is proposed to manufacture.

The choice of the raw material suitable for the economic manufacture of clay roofing-tile is most difficult for one not directly engaged in the industry, and even an experienced person will find it difficult to choose a material suitable for any other type of tile than that with which he is familiar. A person reporting favourably on a material for this purpose may exercise perfectly sound judgment and yet the manufacturer may find the clay unsuited to his needs because of his viewing the material from a different perspective. To simplify procedure the following criteria and methods of their application are given.

REQUIREMENTS OF CLAY FOR ROOFING-TILE

The ideal raw material might be described as follows:

1. The deposit should be of workable size and the material free from stone or other undesirable materials.

2. The material when wet should develop proper plasticity for the method to be used.

3. The drying shrinkage should be negligible and the drying accompanied by no cracking, warping, nor scumming.

4. When burned it should show a negligible firing shrinkage up to its softening point, burn to such porosity as desired over a range of at least 6 pyrometric cones, and the colours produced should be constant over the same range. It should neither warp nor crack on burning, nor be difficult to rid of its carbonaceous matter.

As no material fulfilling all these ideals is known in Canada, it is necessary to study the properties of many clays, and by elimination to arrive at the materials best suited to the purpose.

Plasticity

Plasticity is inherent in varying degree in all wet clays and shales and can be increased by grinding, ageing, and chemical treatment, and decreased by the addition of non-plastics.

Although many means have been devised for the measurement of this important property, the ceramist continues to employ his sense of feel for determining its value. The usual terms employed in reporting plasticity are "plastic", "fairly plastic", or "short", and the value of such observations is dependent upon the experience of the person making the test.

Besides permitting the material to be easily moulded into desired forms, it can be said generally that:

The greater the plasticity the more water required for proper tempering.

The greater the plasticity the greater the drying shrinkage.

The greater the plasticity the greater the burning shrinkage.

The greater the plasticity the greater the dry strength.

The greater the plasticity the smoother the finish.

In the manufacture of the soft-mud (or plastic) type, (hand or machine), plasticity in the raw material need not be so high as required in the stiff-mud (or stiff plastic) process. As concerns the manufacture of dry-press wares, very plastic materials are difficult to process by the dry-press method; a shale or a mix containing a small percentage of clay substance being more suited to this process.

Drying Properties

After shaping, all tempering water must be removed either in a dryer or during the early part of the burn. This drying is accompanied by shrinkage, which is a contributory factor to warping and cracking, therefore in the plastic and stiff-plastic processes, clays of high shrinkage should be avoided.

In testing clays generally for this property the procedure is as follows. Briquettes are made approximately 2 inches by 1 inch by 1 inch and their wet volumes are determined; they are then dried and their dry volumes are determined. The difference in volume is the drying volume shrinkage. By dividing this difference by the dry volume and multiplying by 100, the per cent volume drying shrinkage is calculated, and this is transposed according to the following formula into per cent linear drying shrinkage.

$$\text{Per cent linear shrinkage}\left(= 100\left[\sqrt[3]{\frac{\%\ \text{Volume shrinkage}}{100}+1} - 1\right]\right)$$

Unless otherwise stated all drying shrinkages in this report are calculated from volume shrinkages, using the dry volume as a basis, and are expressed as per cent linear shrinkage.

This method, although suitable for the studies of the clays and shales generally, does not afford opportunity for general observation of materials for their suitability for the manufacture of roofing-tile. For this purpose a very simple method followed in the main by Worcester[1] seems to be quite satisfactory and more illustrative than the method previously noted.

The material after being ground through a standard 28-mesh screen is tempered with water, shaped into balls, and placed in a damp box for 48 hours. The aged material is then re-worked thoroughly and divided into two portions, one to be extruded through a die into a ribbon 6 inches wide by ½ inch thick. This is cut into 14-inch lengths and lengthwise into 3 strips 2 inches wide. These are placed on boards to dry at room temperature. The other portion is hand-moulded into strips 14 inches long, 2 inches wide and ½ inch thick. In the plastic state, knife edge marks are placed 10 inches apart on each strip. When all the strips, extruded and hand-made, have become "leather" hard they are placed in a drying-oven regulated at 105° to 110° C. for 24 hours, after which the distance between the knife-edge marks is remeasured, the difference noted, and the direct linear shrinkage percentage calculated.

Between 4 and 8 per cent is the usual linear drying shrinkage of clays, shales being generally lower. A shrinkage higher than 8 per cent is apt to cause trouble.

The shrinkage test strips are used in several of the tests which follow.

Drying Warpage. Warpage on drying is apt to occur in high-shrinkage clays. This can be noted on the strips that are used in the determination of drying shrinkages.

[1] Loc. cit.

Cracking in Drying. Cracking in the drying of clay wares is generally caused by the methods of shaping and drying employed and can usually be overcome by the results of a little study. There are, however, certain clays that have a tendency to crack when drying. Such a clay usually gives considerable trouble and should not be chosen for the manufacture of roofing-tile.

A very satisfactory test for this property is to mould several 2-inch cubes from the aged balls mentioned under drying shrinkage, and place them directly in an oven maintained at 105° to 110° C. Clays that have a tendency to crack on drying will give evidence of it in this test.

Scumming. The presence of certain soluble salts in a clay will cause ware made from it to develop drying scum.

Observations of the test strips after slow drying should reveal any scum present. The observation should, however, be followed by an examination of the final burned specimens since it is not always easily recognized on the dry specimen.

This is a very important consideration in clays to be used for the manufacture of roofing-tile because scum masks the true colour of the ware.

If scumming occurs, the use of barium salts (barium carbonate being the most generally used) in the tempering operation is advisable.

Dry Strength. In order to permit of safe handling and setting from dryer to kiln, it is necessary to have a material of good dry strength. For the manufacture of roofing-tile a test described by Worcester (*loc. cit.*) is practical and informative. It is an arrangement by which a load is applied by means of shot to the centre of a dried bar held on knife edges 10 inches apart, the load necessary to break the bar being recorded, in pounds per square inch (cross-sectional area), as the dry strength.

For accurate information it is advisable to calculate the modulus of rupture of the dried bar rather than report the results in pounds per square inch.

The usual method of conducting dry-strength tests is described on page 460, Journal of the American Ceramic Society, June, 1928, Vol. 11, No. 6, as a standard test. This test, however, is really a measure of the bonding power of a clay, rather than of its dry strength, as the test is run on a mixture of 50 per cent sand and 50 per cent clay.

The dry strength of natural materials is affected by:—

1. Fineness of grain—the finer, the higher the strength.
2. Per cent clay matter—the higher, the higher the strength.
3. Shaping process—stiff plastic gives highest strength.
4. Ageing—increases dry strength.

The dry strength can be improved by extended grinding and by ageing. Organic binders such as dextrin or starch might also be used for this purpose.

Refractoriness

The refractoriness (represented by the pyrometric cone equivalent, P.C.E.) is important in the selection of a roofing-tile clay only in so far as it affects the burning and burned properties, and its effect can be judged from these considerations.

Burning and Burned Properties

The most important criteria of clays and shales for any ceramic purpose are undoubtedly the manner in which they behave when heated to increasingly higher temperatures and the physical properties of the resulting products. Unlike other properties of argillaceous materials, they have not been successfully altered. It is true, that materials, the burning and burned properties of which have not been fully satisfactory, have nevertheless been used successfully in commercial production. To do this, however, called for expert manipulation and the product was supplied to markets only where cheaper substitutes were not available. In this age of efficient transportation and of industries of widening scope, it is inadvisable to use a material having inferior burning, and burned, properties for the production of roofing-tile.

The criteria of importance as regards the burning, and burned properties of a material are:—

1. Burning shrinkage.
2. Rate of shrinkage at various temperatures.
3. Burning warpage tendency.
4. Absorption of burned product at various finishing temperatures.
5. Colour of burned product.

All these factors go to determine the burning range of the material.

Burning Range. The range of temperature over which the material will produce marketable ware of uniform physical properties.

For determining the burning and burned properties of clays and shales, the method (in general) suggested by the American Ceramic Society is followed. Briquettes, similar to those described under "Drying Properties", having been dried and their volumes recorded, are burned to predetermined cones, depending upon the already known pyrometric cone equivalent (fusion point) of the materials being studied. The burning schedule used is described as follows:

From room temperature the kiln is brought up to 100° C. in one hour and held at that temperature for three hours, after which the temperature is raised at a rate of 50° C. per hour until 800° C. is reached, the rate of temperature increase is then lowered to 25° per hour until a temperature of 1000° C. is reached, after which the rate of 50° C. per hour is again used till the completion of the burn. The kiln used is gas-fired and capable of attaining cone 20.

Upon completion of the burns the volumes of the briquettes burned to each cone are determined, and the volume burning shrinkage is determined and the linear shrinkage calculated.

The burned briquettes are weighed dry and then weighed saturated with water, and the per cent absorption calculated according to the following:

$$\frac{\text{Wet weight} - \text{dry weight}}{\text{Dry weight}} \times 100 = \text{Per cent absorption.}$$

The per cent apparent porosity is calculated as follows:—

$$\text{Per cent apparent porosity} = \frac{\text{Weight, water-saturated burned briquette, grms} - \text{Weight, dried burned briquette, grms.}}{\text{Volume of burned briquette, c.c.}} \times 100$$

In addition to the briquettes, strips made similarly to those noted under "Drying Properties" should be used for determining the burning and burned properties. Small briquettes never give an indication of burning warpage, which is so important in roofing-tile manufacture. By burning at least 3 strips approximately 14 inches by 2 inches by ½ inch to all cones over the determined firing range, a check will be had on the per cent linear-shrinkage, absorption, and colour, and some idea of the tendency of the material to warp may be obtained.

Shrinkage. In general, clays begin to shrink at red heat and continue to do so at varying rates until a temperature is reached at which the shrinkage ceases. The ranges over which clays show no change in dimension (this is termed the equal-shrinkage range) vary with the material as do the rates of shrinkage. Some clays have no equal-shrinkage range but begin, immediately shrinkage has ceased, to expand, which is caused by the overfiring of the material.

In the manufacture of roofing-tile the importance of shrinkage cannot be over-emphasized, directly connected as it is with the absorption and finished dimensions of the burned product. The slower the rate, the lower the maximum shrinkage and the longer the range of equal shrinkage, the better is the material suited for use in the roofing-tile industry.

Figure 6 illustrates a poor shrinkage curve and a good shrinkage curve.

For the manufacture of porous roofing-tile the shrinkage curve of the clay need not be so flat as shown in Figure 6 by the solid line, though it should have a much less steep curve than shown in the same figure by the dotted line. For the manufacture of vitrified tile a curve more nearly similar to the solid line is most important.

The temperature variation between top and bottom of a kiln is often very great, and this with a material of greatly varying firing shrinkages over that temperature range would result in ware of varying dimensions. Not only is the amount of firing shrinkage important as it controls the final absorption of the ware, but so is the rate of skrinkage, owing to the need of having tile from different parts of a kiln all of the same finished dimension.

Unless otherwise stated, all fire shrinkages in this report are calculated from the volume shrinkages, using the dry volume as a basis, and are expressed as per cent linear shrinkage. The equation used to calculate the per cent linear, fire shrinkage from the per cent volume shrinkage is:—

$$\text{Per cent linear fire shrinkage} \left(= 100 \left[\sqrt[3]{\frac{\%\ \text{Volume shrinkage}}{100} - 1} + 1 \right] \right)$$

Warpage. This is an important consideration in the study of clays for use in the roofing-tile industry, particularly so when vitrified tile are being contemplated. Worcester (*loc. cit.*) claims that the warpage tendency of raw materials is dependent upon their vitrifying qualities. His experience showed that below cone 010 burning warpage was negligible. He recommends running burning-warpage tests from cone 010 to complete maturity, in order to learn the cone at which the rate of warpage increases noticeably in comparison to the rates of change in fire shrinkage and absorption, and that cone will be the cone at which warpage is apt to be most severe. However, all tests in this connection are comparative because so much depends upon the experience of the operator. The test given above will give comparative results produced under an exaggerated condition; they can be regarded only in this sense.

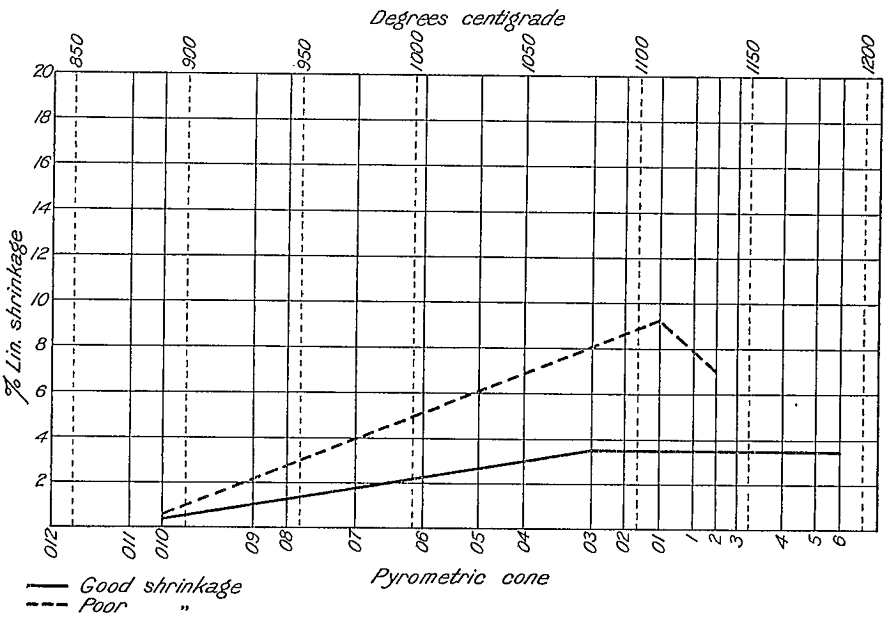

Figure 6. Fire-shrinkage curves.

For studying warpage the following procedure has been followed. Two straight 14-inch by 2-inch by ½-inch strips of each material were placed on fireclay knife-edges (10 inches apart) and heated to cones, mentioned hereafter under each material, at the rate of 125°C. per hour. The warpage was measured by placing a straight-edge along the line of the two suspension-points and the distance between the straight-edge and the deepest deformation measured. The distance was divided by 10 and multiplied by 100 and the result recorded as per cent warpage.

Oxidation Properties. There are three factors that contribute to the difficulty of burning clay-wares containing carbonaceous matter, the percentage of carbonaceous matter present, its nature, and the temperature at which vitrification begins. Clays containing rather high percentages of carbonaceous materials that have comparatively high points of vitrification (fireclays) offer no difficulty during the oxidation period; on the other hand, there are materials in which the percentage of carbonaceous matter may be much lower, but having a point of vitrification so close to the oxidation it is difficult to complete the oxidation before the pores become sealed, with consequent bloating. A material cannot be chosen, however, merely for its ease of oxidation, inasmuch as there are more important considerations, and this test should be reserved until all other tests have shown which materials otherwise are most suitable. By careful manipulation in the plant, all other properties of the material being satisfactory, the oxidation problem can be successfully solved.

As an indication of the ease with which a material can be oxidized, two brick (approximately 8 inches by 4 inches by 2 inches) made from the tempered mass described on page 41 and burned face to face along with the briquettes, as described on page 43, will prove of value.

Burned Colour. At one time burned colour would have been one of the most important considerations in recommending clays for roofing-tile. Although still important, the fact that flashing and surface treatments of tile are commonly practised makes its significance rather difficult to assess. It is always desirable to have a pleasing burned colour, the usual choice, as in the past, being red, though for glazing a light-coloured product is more desirable. For slipped or sanded surfaces the colour is not important as the desired colour is obtained from the coating. In this report good colours are treated as a deciding factor, all other properties being equal.

General Conclusions

The burning and burned properties of clays are the only ones of all the foregoing important properties that have yet to be successfully and economically altered. This and the fact that good burning ranges are so necessary to the production of roofing-tile lead to the conclusion that the burning and burned properties of a clay are of paramount importance in regard to its suitability for the manufacture of this commodity. Clays and shales having short burning ranges and rapid changes in firing shrinkage and absorption, unless they have some outstanding compensating feature, are not considered in this report to be of roofing-tile quality.

The use of inferior raw materials, although excusable in the past, is today a sign of poor judgment.

Various kinds of clay and shale occur throughout the eastern provinces, among which are fireclays, stoneware clays, kaolin, and materials the chief use of which is for the manufacture of heavy clay products. In this report they are treated, by province, as to their suitability for the economic production of roofing-tile, attention being directed to those materials only that come nearest to the desired type. Other materials are mentioned only when they occur in abundance, near transportation and in close proximity to markets.

Prince Edward Island

Plasticity

Nearly all the clays and shales (which are soft) on Prince Edward Island develop a working plasticity. Some develop sufficient plasticity to permit of their use by the stiff-mud (stiff plastic) process, whereas others can be shaped only by hand or by the soft-mud process.

Drying Properties

They dry readily, being without any inherent warping or cracking tendencies. Their linear drying shrinkages vary from 2 to 3 per cent in the more silty clays and from 4 to 6 per cent (average 5 per cent) in the more plastic. They dry without scumming. Their dry moduli of rupture vary from 50 pounds in the more silty to 150 pounds per square inch in the more plastic.

Burning and Burned Properties

For the most part, the clays of Prince Edward Island burn to pleasing shades of red at cone 05, the red becoming deeper as the burning temperature is increased. Their linear burning shrinkages increase from 3 per cent at cone 06 to 10 per cent at cone 01, the absorption of the burned product dropping from 10 per cent to less than 1 per cent at these respective heat treatments. The range over which the materials burn with less than 4 per cent absorption, without evidence of overfiring, varied from 25°C. to 80°C. They give no trouble as regards oxidation. Burning warpages determined on several typical clays from this province were found to be as follows:

Cone 07	Cone 06	Cone 05	Cone 04
%	%	%	%
0·4	0·4	1·2	1·3
3·0	3·4	3·4	7·1
1·7	2·8	....	3·0
1·5	1·5	4·7	5·5

The pyrometric cone equivalents (softening points) of the Prince Edward Island clays vary from cone 3 to cone 12.

The clays and shales of Prince Edward Island are not generally suited for the manufacture of vitrified roofing-tile, but there are several deposits, of which the following is typical, that might be considered in this connection.

Location: On the northwest coast of Prince Edward Island, 4 miles from Tignish and 6 miles from North Point.

Water of plasticity, 26·2 per cent.
Drying shrinkage, 7·4 per cent.
Clay substance, 75·7 per cent.
Slaking time, 4 min. 42 sec.
Plasticity, Good.
Non-plastics, 24·3 per cent.
Dry modulus of rupture, 118·2.

Burning and Burned Properties.

Cone	010	06	03	01	1	2	3
Colour	Salmon.	Fair brick red.	Dark brick red.	Dark brick red.	Dark brick red.	Chocolate.	Bloated.
Firing shrinkage, %	1·1	7·0	10·6	10·7	10·3	8·3	
Absorption, %	15·4	5·9	N.	N.	N.	N.	

Warpage tests run on this material gave the following results:—

Cone	07	06	05	04
	3·0	3·4	3·4	7·1

N = Negligible.

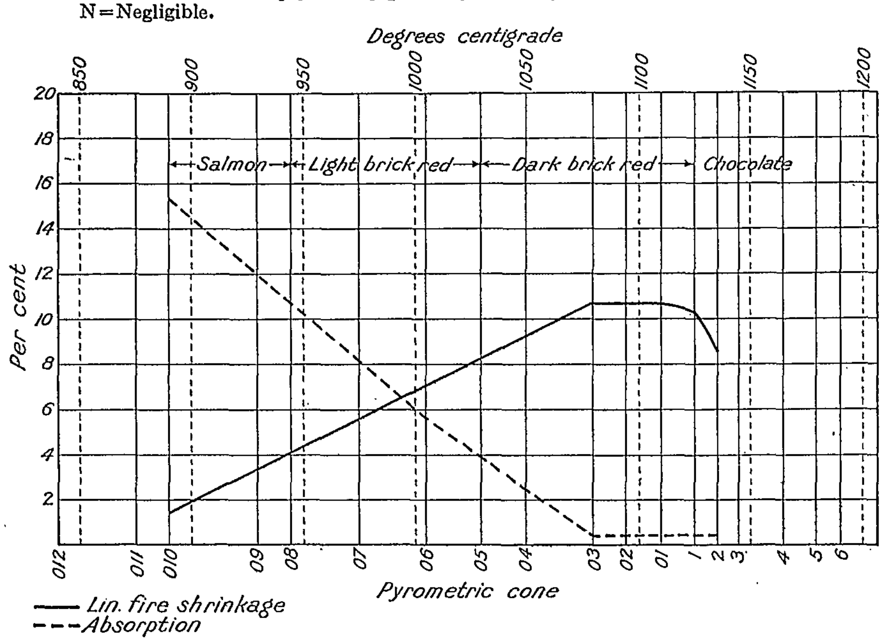

Figure 7. Tight-burning Prince Edward Island shale.

The above figure shows rather steep shrinkage and absorption curves. After cone 02 the shrinkage curve takes a drop, showing expansion (over-firing). The range of nearly equal shrinkage lies between cone 04 and cone 02. Ware burned to these temperatures would show an absorption of from 3 per cent to a negligible quantity. This is a range of only three cones, which is not very large. The colour over this range is good. This is not an ideal material but is representative of the best known to occur on Prince Edward Island.

For the manufacture of porous roofing-tile, certain materials are worthy of consideration. The following is typical of these:—

Location. Clay exposed on the Dominion Experimental Farm, 1½ miles north of Charlottetown.

Water of plasticity, 22·8 per cent.
Drying shrinkage, 2·3 per cent.
Slaking time, 6 min. 6 sec.
Plasticity, Fair.
Dry modulus of rupture, 53·9.

Burning and Burned Properties.

Cone	010	06	03	01	1	2	3	4	5
Colour	Salmon.	Deep salmon.	Fair brick red.	Good brick red.	Good brick red.	Dark brick red.	Chocolate.	Chocolate.	Silver
Firing shrinkage, %	N.	N.	3·8	8·2	9·0	10·0	9·6	9·1	8·9
Absorption, %	8·8	6·3	6·8	3·9	2·7	N.	N.	N.	N.

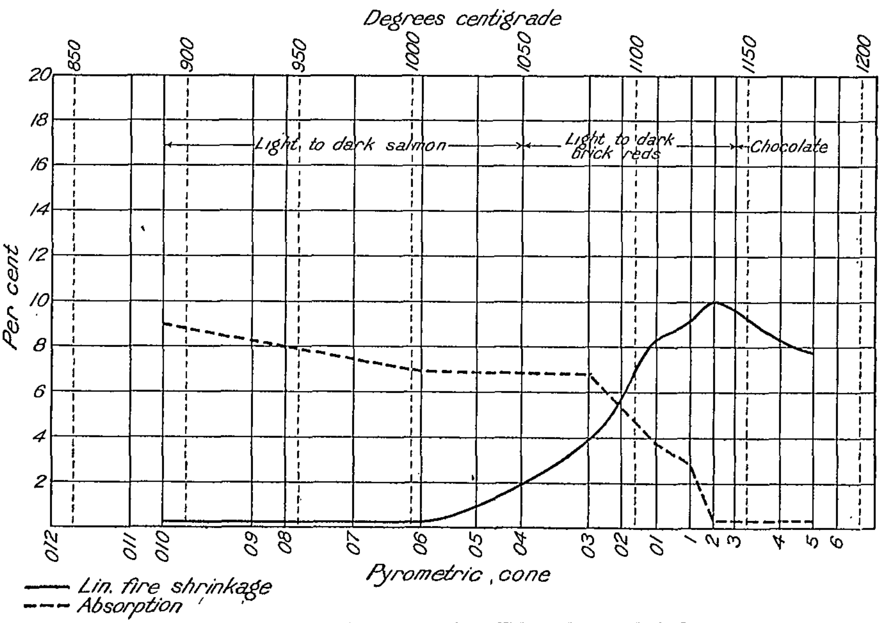

Figure 8. Open-burning Prince Edward Island shale.

Owing to the facts that it shows equal absorptions when burned between cone 06 and cone 03, that the shrinkage difference over this range of four cones is not excessive (3 per cent), and that vitrification does not proceed rapidly until cone 03 is reached, this material is chosen as representative of the best materials for porous tile occurring on Prince Edward Island.

Nova Scotia

Unlike Prince Edward Island, this province presents exposures of many geological ages containing clays and shales of various characteristics. Although it cannot be said that the province has been completely prospected, nevertheless sufficient work has been done to give an indication of the nature of the materials to be found.

The shales found and tested were red and buff-burning and their general properties were such as would not make them of particular interest to the roofing-tile manufacturer. Many of the outcrops sampled showed the presence of limestone, sandstone, and conglomerate, and the beds have an undesirable variability. The shales vary from sandy to plastic materials, having good drying properties and in general exhibiting short burning ranges.

The clays tested may be divided into red-burning and buff-burning clays that vary greatly in their geological history and in their general properties. The red-burning clays are of Pleistocene age, of glacial or marine origin, and the buff-burning clays occur in the coal measures and in deposits of Mesozoic age. The glacial and marine clays are used for the manufacture of soft-mud (plastic) and stiff-mud (stiff plastic) building-brick, and for the manufacture of hollow building- and drain-tile, and in the past the marine clay has been used for the manufacture of pottery. Deposits occur throughout the province and vary in the amount of stone and silt present in the glacial clay and of sand laminae in the marine clay. Their general properties are similar, though the marine clays are slightly less refractory than the glacial clays, representative samples of the former fusing at approximately cone 1 and of the latter at cone 3.

The marine clays have been more used in the clay-working industry than have the glacial clays, owing principally to their freedom from stone; they are often so plastic as to require additions of non-plastics.

Both the glacial and marine clays exhibit short burning-ranges, which are illustrated in Figure 9, and which make them of doubtful value for the manufacture of roofing-tile.

The buff-burning clays are of refractory or stoneware quality and for that reason are not described.

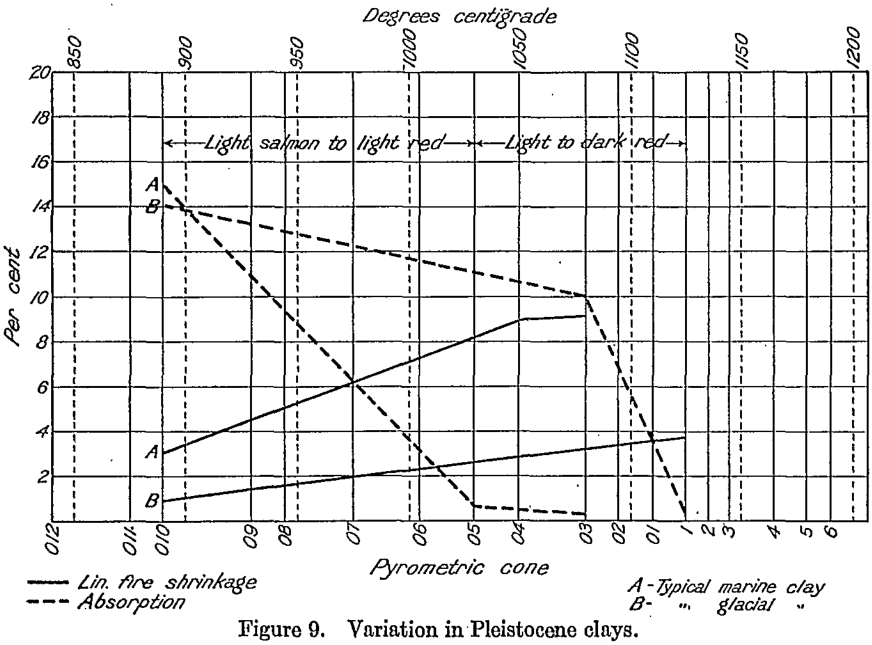

Figure 9. Variation in Pleistocene clays.

The most interesting material from Nova Scotia burned to an exceptionally pleasing red and is described as follows:—

Locality. On the east coast of Northumberland Strait, 30 miles northeast of New Glasgow, at Ponds, Nova Scotia.

Deposit. Three feet of this clay is exposed under an overburden of 3 feet of glacial clay, but the total depth of the deposit is not known. It is known to occur over considerable area with the overburden increasing to 20 feet at about one-quarter mile from the exposure.

Natural and Wet Properties. The material is red, becoming a brilliant red when wet. It develops fair plasticity when tempered with 23 per cent of water.

Composition. A washing test showed the material to contain 54 per cent of non-plastic material, which was principally fine quartz sand.

Drying and Dried Properties. Briquettes, strips, and flat tile made from this material presented no drying problem other than that of developing a white scum that could easily be corrected. The average calculated linear drying shrinkage was 5·1 per cent. When dry the material can be safely handled.

Burning and Burned Properties.

Cone	010	06	05	04	02	01	1	2
Colour	Light red.	Red.	Red.	Dark red.	Dark red.	Dark red.	Dark red.	Dark red.
Hardness	Fairly hard.	Hard.	Hard.	Hard.	Very hard.	Very hard.	Very hard.	Very hard.
Firing shrinkage, %	N.	2·6	2·7	3·1	6·7	6·5	6·4	7·4
Absorption, %	15·5	13·0	8·1	7·5	2·6	2·9	4·4	1·8

The P.C.E. of this material is cone 2.

The material presents no particular burning problems.

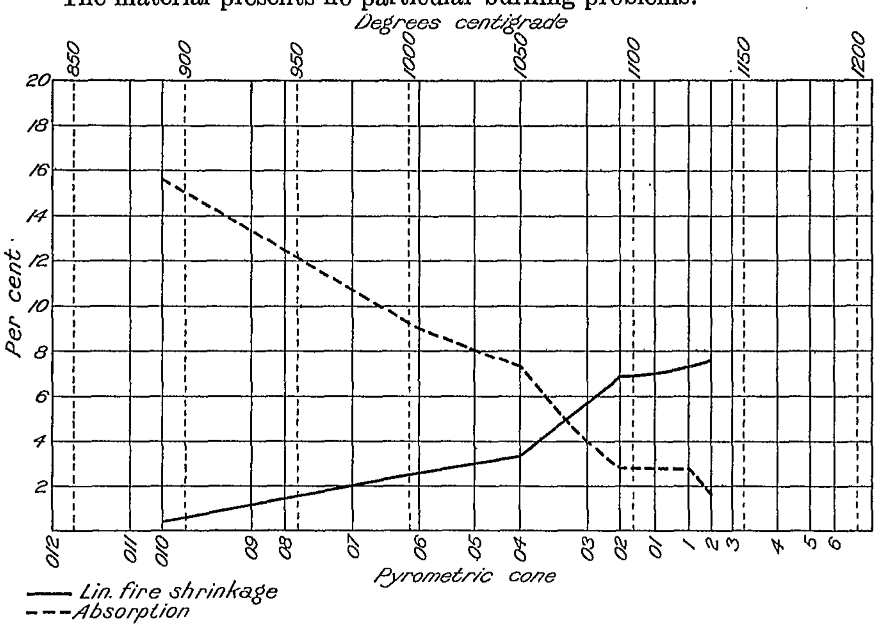

Figure 10. Clay from Ponds, N.S.

Warpage tests run on this sample have the following results:—

Cone	07	06	05	04
Warpage %	0·8	1·1	2·6	4.2

The material is not suited to the manufacture of vitrified roofing-tile. Its burning and burned properties over the range shown in Figure 10 are not the most desirable, owing to the sudden change that takes place between cone 04 and cone 02. The exceptionally fine colour that it produces when burned, however, together with the possibility of obtaining ware varying from 10 to 8 per cent absorption from cone 06 to and including cone 04, makes it a material worthy of consideration for the manufacture of porous tile.

New Brunswick

Many clay and shale deposits occur throughout the Province of New Brunswick and the quality of the clay often varies with the deposit. Some are suitable for the manufacture of low-grade refractories and others for the manufacture of common building brick only. Good grades of face brick, building tile, and common brick are manufactured in several localities in the province.

To date there has been no roofing-tile made in the province but in the Upper Carboniferous exposures that are found at Stoneham, Chatham, and Clifton occurs a red shale, interstratified with bands of grey and green shales, that should prove of value in the manufacture of roofing-tile.

The following gives the essential information about these outcrops:—

Upper Red Shale

Location. Along shore of Chaleur Bay, Stonehaven, near wharf in front of property of John Chamberlain.

Deposit. The red shale lies in a bed 15 feet thick, is underlain by a bed of soft sandstone 3 to 5 feet in thickness, which in turn is underlain by a 15-foot bed of interstratified red and green shales. Green shale is also scattered throughout the red shale occurring as specks or nodules.

Plasticity. The upper red shale was found to be non-calcareous, easily ground, and to develop good plasticity when tempered in a wet pan with 22 per cent water.

Slaking. The material slaked readily in water, the average slaking time of a 1-inch cube of a mixture of 50 per cent ground material and 50 per cent potter's flint being 2 minutes 10 seconds.

Composition. A washing test gave the following results: 45·1 per cent clay matter, 54·9 per cent non-plastics.

Drying Properties. Flat tile, strips, and briquettes, made from a tempered mass by hand, through a die (stiff-mud), and by dry-press, presented no drying difficulties. There is a slight tendency to warp in drying. There was no noticeable scum and the dried ware was of such strength as to permit of safe handling.

Burning and Burned Properties—

Cone	010	06	05	04	03	02	01	1	2
Colour	Salmon.	Red.	Red.	Red.	Red.	Red.	Dark red.	Dark red.	Dark red.
Hardness	Fairly hard.	Hard.	Hard.	Hard.	Hard.	Very hard.	Very hard.	Very hard.	Very hard.
Firing shrinkage, %	Slight expan.	4·6	4·3	6·5	6·7	6·7	6·7	6·9	7·1
Absorption, %	13	4·9	4·5	3·3	1·5	N.	N.	N.	N.

N. = Negligible.

The P.C.E. (fusion point) of the material is cone 3.

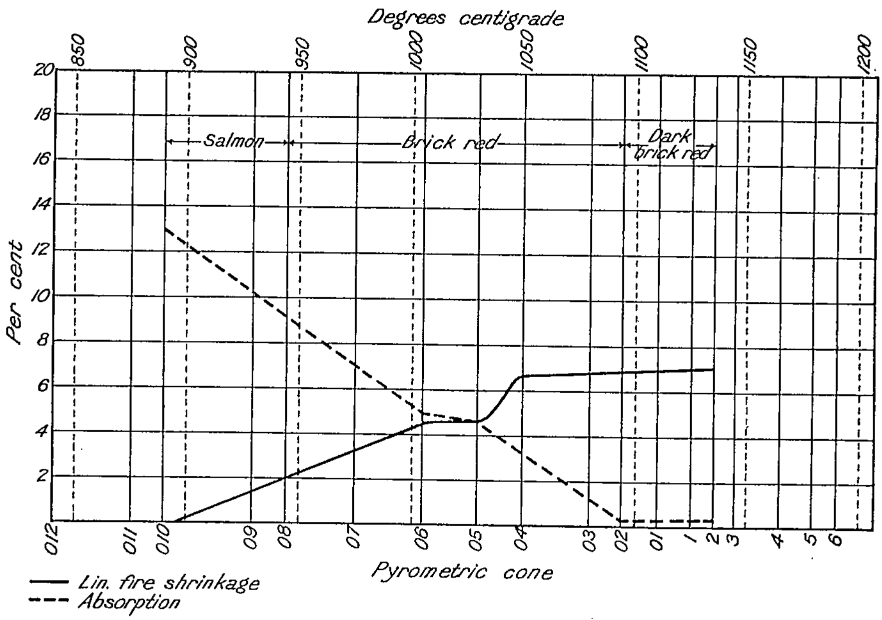

Figure 11. Stonehaven red shale.

Warpage tests run on this sample gave the following results:—

Cone	07	06	05	04
Warpage, %	1·6	2·7	2·8	5·6

Lower Green Shale

Location. Same location as given for foregoing sample.

Deposit. This sample represents the green shale that occurs below the red shale described in the foregoing tests.

Plasticity. It was a hard shale that was easily ground and developed good plasticity when tempered with 21 per cent of water.

Slaking. This shale slaked readily in water. The average slaking time of 1-inch cubes made of 50 per cent shale and 50 per cent potter's flint was 4 minutes 40 seconds.

Composition. A washing test showed the shale to be composed of 35·2 per cent of clay matter and 64·8 per cent non-plastics.

Drying Properties. Briquettes, strips, and flat tile made from this material presented no drying difficulty other than the development of a white scum. The linear drying shrinkage was 5·4 per cent and the dried ware was of sufficient strength to be safely handled. There is a slight tendency to warp in drying.

Burning and Burned Properties.

Cone	010	06	05	04	03	02	01	1	2	3
Colour	Light salmon.	Light red.	Red.	Red.	Red.	Red.	Red.	Dark red.	Dark red.	Dark red.
Hardness	Soft.	Hard.	Hard.	Very hard.	Very hard.	Very hard.	Vitrified.	Vitrified.	Vitrified.	Vitrified.
Firing shrinkage, %	N.	5·2	5·5	7·7	6·9	7·3	7·7	7·7	7·7	8·5
Absorption, %	12·5	6·0	4·5	4·0	2·5	2·3	1·6	1·5	1·0	1·0

The red colours from cone 05 to and including cone 02 are very good. The darker reds, if not so pleasing, are good. The scum showed badly on the burned ware.

Warpage tests run on this sample gave the following results:—

Cone	07	06	05	04
Warpage, %	1·8	2	2·2	4·8

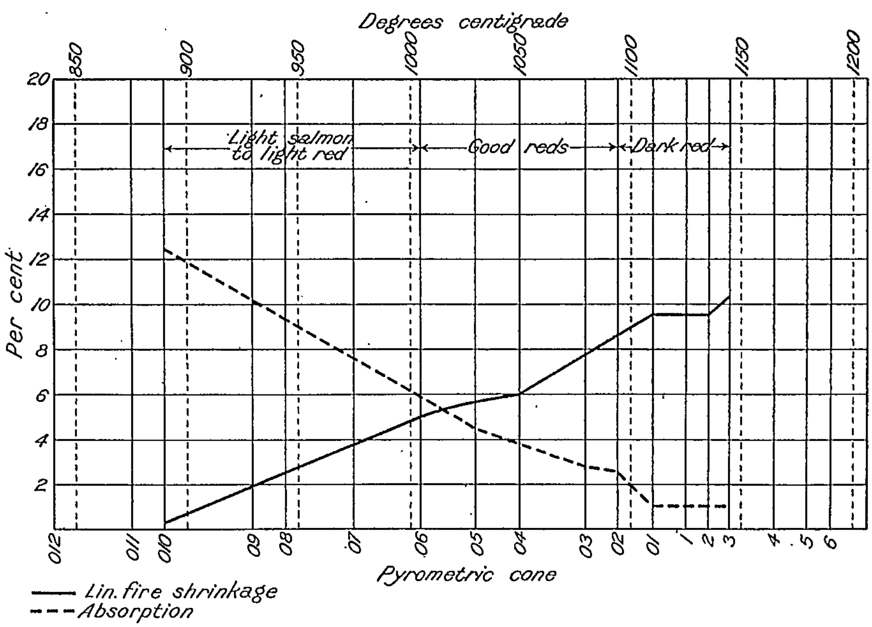

Figure 12. Stonehaven green shale.

Weathered Upper Red Shale

Location. Same as preceding two materials.

Deposit. This represents the shale that has weathered to a clay to a depth of approximately 4 feet. It is not in evidence on the coast, but ¼ of a mile inland it is found underlying 8 inches of loam.

Natural and Wet Properties. The shale was easily ground and developed good plasticity when tempered with 20 per cent water.

Slaking. The material slaked readily in water. The average slaking-time of 1-inch cubes made of 50 per cent of the ground material and 50 per cent potter's flint was 12 minutes 5 seconds.

Composition. A washing test showed the material to contain 84·7 per cent clay matter and 15·3 per cent non-plastics.

Drying and Dried Properties. Briquettes made from this material presented no drying difficulty. The average linear drying shrinkage was 7·6 per cent. When dry, the material is of sufficient strength to permit of safe handling. There is a slight tendency to warp in drying.

Burning and Burned Properties.

Cone	02	01	1	2	3	4	5	6	7	8
Colour	Red.	Dark red.	Dark red.	Dark red.	Dark red.	Dark red.	Dark red.	Dark red.	Dark red.	Dark red.
Hardness	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.
Firing shrinkage, %	8·2	9·6	9·6	9·6	8·7	—	8·7	8·7	8·3	5·6
Absorption, %	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.

N.=Negligible.
Colours from cone 02 to and including cone 7—Good.
P.C.E. Cone 10.

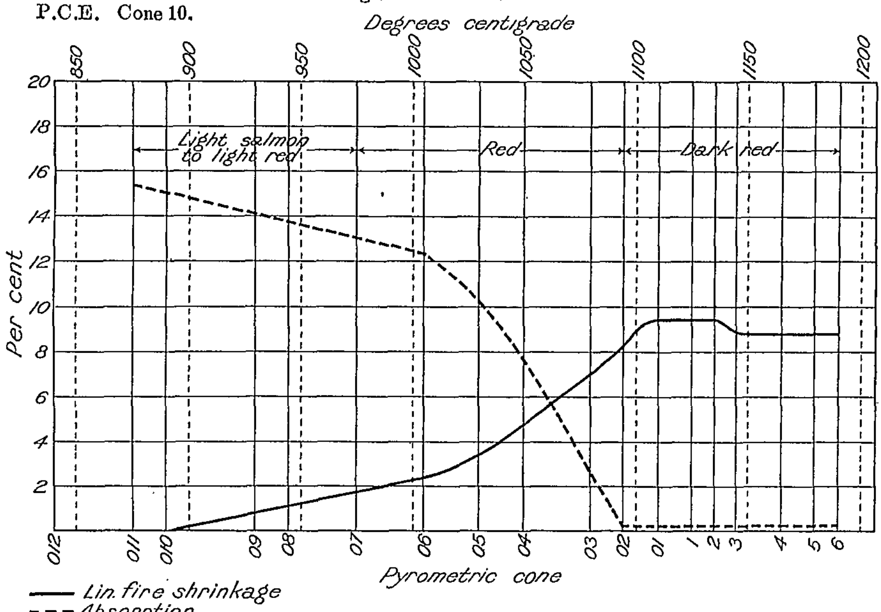

Figure 13. Stonehaven weathered shale.

Chatham Shale

Locality. West bank of Morrison Brook, 10 miles southeast of Chatham, N.B.

Deposit. The bed is exposed along the main highway to a depth of about 15 feet and extends over a considerable area.

Natural and Wet Properties. The shale is red and green in colour, grinds easily and develops good plasticity when tempered with 29 per cent of water.

Slaking. The average slaking-time of 1-inch cubes made of 50 per cent of the shale and 50 per cent potter's flint was 5 minutes 35 seconds.

Composition. A washing test showed the shale to be composed of 43 per cent clay matter and 57 per cent non-plastics.

Drying and Dried Properties. Briquettes, strips, and flat tile made from this shale presented no drying difficulty. The average linear drying shrinkage was 6·3 per cent. The dried ware was of sufficient strength to be safely handled. There is a slight tendency to warp on drying.

Burning and Burned Properties.

Cone	010	06	02	01	1	2	3	4	5	6	7	8
Colour	Light red.	Light red.	Light red.	Red.	Red.	Red.	Dark red.	Dark red.	Dark red.	Dark red.	Dark red.	Dark red.
Hardness	Hard.	Hard.	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.	Very hard.
Firing shrinkage, %	N.	0·8	5·6	6·3	6·8	7·1	7·2	7·4	6·7	7·1	6·7	4·8
Absorption, %	15·5	13·0	3·7	2·3	1·6	1·2	N.	N.	N.	N.	N.	N.

N. = Negligible.

Briquettes showed a slight white scum.

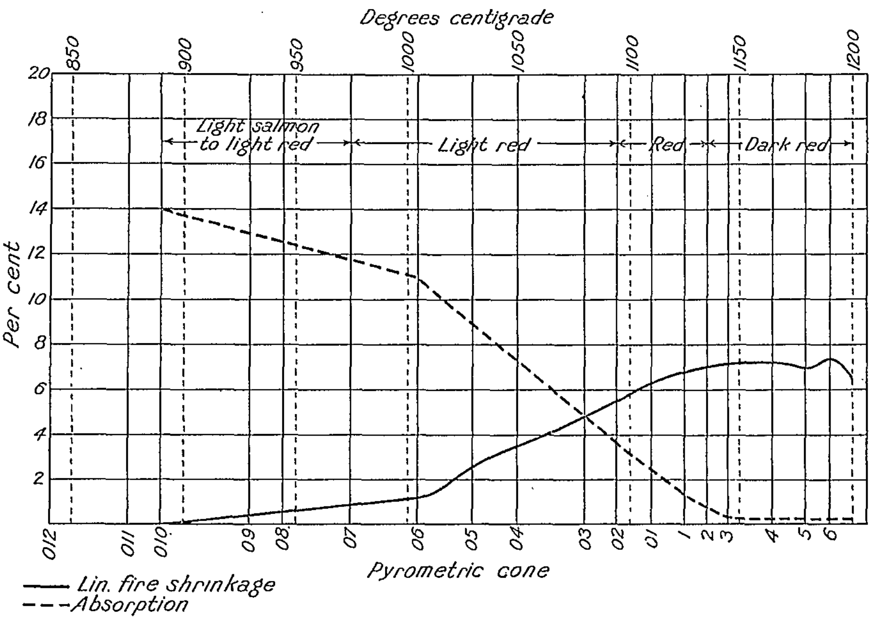

Figure 14. Chatham shale.

Colours were good from cone 02 to and including cone 7. The material flashes readily to good blacks.

Warpage tests run on this material gave the following results:—

Cone....................	07	06	05	04
Warpage, %............	1·3	1·4	1·7	3·2

The foregoing materials, owing to their equal firing-shrinkage ranges and their low absorption over long ranges, are considered as the most suitable materials occurring in New Brunswick for the manufacture of vitrified roofing-tile. They stand out as representative of the best material in eastern Canada for the manufacture of vitrified tile.

For the manufacture of buff-coloured roofing-tile for glaze or engobe application, reference is here made to the buff-burning clays found in the Minto coal field. These are the undershales occurring beneath the coal seams. For detailed information on them, see the following reference[1] and also the report by Frechette and McMahon on the clays and shales of the Grand Lake coal area.[2]

Although other kinds of clay and shale than those referred to above occur throughout the province, they have no outstanding property that would make them of value to the roofing-tile industry. Keele's reports as cited above may be referred to for information concerning them.

Quebec

Quebec contains, in addition to deposits of Queenston, Utica, and Lorraine shales, which are described under "Ontario," the following three types of shales: those of the Sillery and Levis formations, and of the Devonian system.

Sillery Shale

The Sillery shales are exposed along Bayer River, and at St. Charles de Bellechasse. They are purple, red, green, and black in colour and occur interbedded with sandstone. They develop only fair plasticity as they are of a decided slaty nature. This is a possible reason why they have not been used in the ceramic industry. Their burning range, however, is worthy of note and the following test made by Keele is given herewith:

He found the material to grind easily and slake readily in water and when wet to develop fair plasticity. Briquettes made from the material gave no trouble in drying and the measured linear drying shrinkage was 4 per cent.

Material similar to this is known to occur a short distance east of Apollinaire Station and generally these shales should be further investigated as to their suitability for roofing-tile manufacture. Close at hand there are occurrences of Pleistocene clay that could be used for improving their working properties.

[1] Keele, J.: Clay and Shale Deposits of New Brunswick, Memoir 44, No. 37, Geological Series, Geological Survey, Canada, 1914.
[2] Investigations in Ceramics and Road Materials, Mines Branch, Department of Mines, 1927.

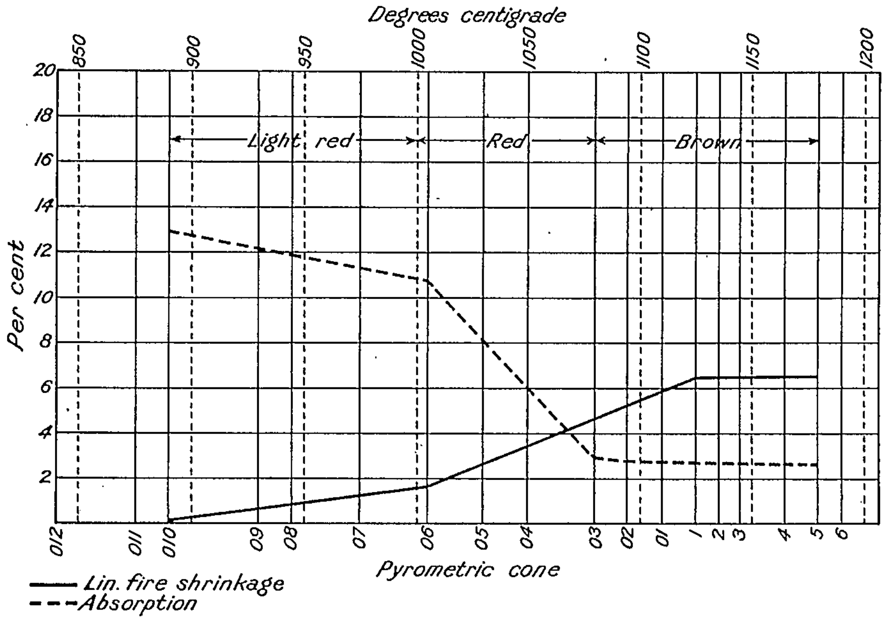

Figure 15. Sillery shale.

Levis Formation

This formation covers an area of only a few square miles in the northern part of Levis County, a shale member of it outcropping along the roadside near Ruel Siding and St. Joseph.

Tests.[1] The shale is grey and rusty in colour, develops fair plasticity and has good drying properties. It does not weather readily. The drying shrinkage is 4 per cent.

It burns to light reds from cone 010 to cone 06 with an absorption of from 9 to 11 per cent. The fire shrinkage over this range is slightly over 1 per cent. From cone 06 to and including cone 03, the material burns to a good red and the absorption gradually drops to 4 per cent at the latter cone, the fire shrinkage gradually increasing from 1 per cent at cone 06 to 4 per cent at cone 03. After cone 03 is reached the material burns to a dark red up to and including cone 3, over which range the absorption drops gradually to 3 per cent, the fire shrinkage remaining at from 4 to 4½ per cent. After cone 3, the material burns to chocolate and gives evidence of overfiring.

The material, though evidently not of sufficient plasticity to be used alone for the purpose, deserves the attention of anyone interested in the manufacture of roofing-tile; further testing is recommended. Plastic clay occurs nearby, and a small percentage would aid materially in producing the proper degree of plasticity.

[1]Keele, J., Preliminary report of the Clay and Shale Deposits of the Province of Quebec, Memoir No. 64, No. 52 Geological Series, Geological Survey, Canada, 1915.

Devonian

In Bonaventure County greenish shale is found interstratified with hard bands having a total thickness of 30 feet.

Tests. This shale exhibited good drying properties and had a linear shrinkage of 4 per cent. When tempered with 19 per cent of water it developed a very plastic mass.

When burned to cone 010 the material showed a linear firing shrinkage of less than 1 per cent, the product was a pleasing red, and the absorption was 11 per cent.

At cone 03 the firing shrinkage increased to 5 per cent, whereas the absorption of the burned product dropped to 5 per cent and the colour changed to a pleasing darker red than that of the cone 010 product.

At cones 1, 2, and 3, the absorption became negligible and the shrinkage, which had risen to 7 per cent at cone 1, began to lessen, showing over-firing above this cone. The product burned at these temperatures was chocolate coloured.

Due to its fine red colour and general good working properties, Keele recommended this material for the manufacture of roofing-tile.

CLAYS.

The clays found throughout Quebec are similar to those of Ontario, and descriptions given under that province apply.

Ontario

In Ontario, two plants are equipped for the manufacture of roofing-tile; one has been in operation since 1910, the other was established but recently.

Clays and shales are widely distributed in the province, many deposits being at present worked for the manufacture of heavy clay products, of which the chief are face brick, common brick, structural tile and drain tile. All these clays and shales have short burning ranges, and are of the same general character as concerns their suitability for the manufacture of roofing-tile, and therefore by describing the various types, using geological nomenclature for reference, a fair idea of their suitability may be had, although none of the materials have properties that would recommend them highly for this purpose. A firm should attempt their use for the manufacture of roofing-tile only if it has a very capable and experienced staff, and after adequate preliminary testing.

The reason for the short ranges exhibited by these materials is shown in Table I, where it will be noted that they contain considerable amounts of lime, magnesia, potash, and soda.

TABLE I

—	I	II	III	IV	V	VI	VII
SiO_2	56–62	53–62	47·98	53–62	50–52	57–65	34–54
Al_2O_3	16–20	15–19	13·10	16–19	10–16	15–19	10–15
Fe_2O_3	5–14	6–9	4·42	5–8	3–6	5–8	3–6
CaO	0·1–3·6	2–7	12·53	2–7	10–14	2–4	10–24
MgO	0·2–4·0	2–3·5	3·25	2–4·6	3–5	1·5–3·5	0·6–5·0
K_2O	1·6–6·7	3–4	3·39	2·5–3·9	2–3	2·2–3·2	1–4
Na_2O		0·46–0·78	0·78	1·3–2·3	1–3	1·5–3·0	1–3

I Lorraine shale.
II Red-burning Queenston.
III Buff-burning Queenston.
IV Red-burning Champlain clays.
V Buff-burning Champlain clays.
VI Red-burning post-glacial clays.
VII Buff-burning post-glacial clays.

SHALES

Utica Shale

Outcrops. Exposures of this shale occur in eastern Ontario at Ottawa, Pickering, and between Russell and Sarsfield, and along the shores of Georgian Bay. Near Ottawa the beds lie up to 400 feet in thickness, but at Georgian Bay the thickness is between 50 and 55 feet.

General Characteristics. The shale grinds easily but does not develop good plasticity, the maximum being with 15 per cent water when ground through 16 mesh.

Linear Drying Shrinkage. The material dries with a 3 per cent linear shrinkage and offers no particular drying problem.

Burning Properties. The Utica shales show low fire shrinkage up to cone 03 (3 per cent), there being a gradual increase from ½ per cent at cone 010. The absorption, when burned, drops from 12 per cent at cone 010 to 11 per cent at cone 06, and then rapidly at increasingly higher cones until it is negligible at cone 1. The burned colours are red and pleasing, though not such as would warrant the disregarding of the other burning properties. This material fuses at about cone 3. It contains rather high percentages of carbon and requires careful firing during the oxidation period.

The material has not been used to any great extent in the manufacture of ceramic wares. When used it has been blended with Champlain clay.

Lorraine Shale

The Lorraine shale is used extensively in the province for the manufacture of heavy clay products. It is the only shale being used in Canada for the manufacture of roofing-tile.

Occurrence. Numerous exposures of Lorraine shale occur throughout the southern part of Ontario, though there are many places where it underlies heavy mantles of glacial overburden. The localities where the material is abundant and most easily obtained in Ontario are in Russell, Carleton, York, Peel, and Halton Counties, particularly in the neighbourhood of Ottawa and Toronto.

In practically all exposures of any size, the shale is found interbedded with strata of limestone, which adds difficulty to the quarrying operation.

General Characteristics. The Lorraine is a dark grey shale which grinds easily and develops fair plasticity when tempered with from 14 to 25 per cent water.

Drying Properties. It does not present any difficulty in drying and the measured linear drying shrinkage is approximately 3 per cent, some samples running as high as 7 per cent. The dry strength is good.

Burning Properties. As with other properties, the burning properties of this material vary from location to location.

When burned to cone 010 the material shows fire shrinkage ranging from 0 to 4 per cent, usually about 3 per cent. The absorptions of the products at this cone vary from 10 to 13 per cent, though in some instances they have been found to be as low as 3 per cent and in others as high as 17 per cent.

When burned to cone 06 the accompanying firing shrinkage varies from 1 to 6 per cent (usually less than 5 per cent) and the absorption of the product generally varies from 6 to 8 per cent, there being instances of 2 per cent and 12 per cent absorption.

When burned to cone 03 the firing shrinkage varies from 2 to 10 per cent (usually below 5 per cent), and the absorption of the product ranges from 0 to 11 per cent (usually below 3 per cent).

The Lorraine shale burns to a good red colour, but not over a long range.

Figure 16 gives typical shrinkage and absorption curves of the Lorraine shale.

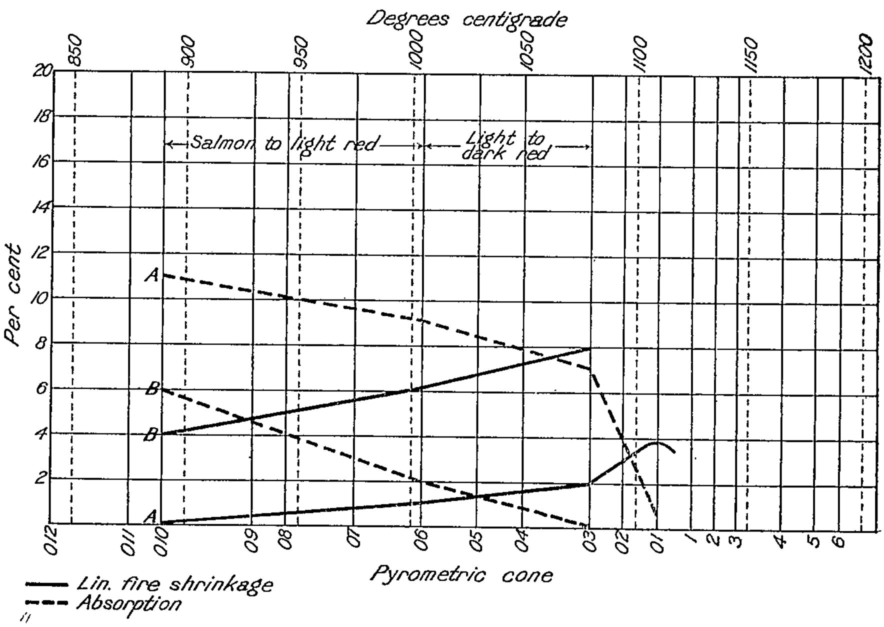

Figure 16. Variation in Lorraine shales.

The P.C.E. of this shale is cone 4.

Queenston Shale

The Queenston shale is used extensively for the manufacture of heavy clay-products in Ontario, its good working properties making it suitable for use in the stiff-mud and dry-press processes. There is no evidence that this material was ever used in the manufacture of roofing-tile.

Outcrops. Exposures of Queenston shale are known to occur at many places in Peel, Dufferin, and Halton Counties, on the interlake peninsula, and it can be traced from Beamsville to Hamilton. In Russell Township in eastern Ontario there is an isolated area where it outcrops but it has not been noted in central Ontario.

General Characteristics. This is a reddish brown, massive shale that weathers readily and may be easily crushed. It develops good plasticity and exhibits no drying faults. The measured linear drying shrinkage usually approximates to 4 per cent. The Queenston shale contains appreciable percentages of lime, magnesia, potash, and soda. *See* Table I.

Burning Properties. The Queenston shale burns red and buff, the most usual colour produced being red. The difference in the burned colour is due to the content of lime, which varies from $1\frac{1}{2}$ to $12\frac{1}{2}$ per cent, the typical shale containing 4 per cent, the difference in lime content being attributed to weathering action.

Buff-burning Shale. The buff-burning Queenston shales have rather different burning properties from the red-burning variety. The absorption of buff-burning shale when burned to cones 010 and 03 lies between 15 and 18 per cent. After cone 03 the absorption decreases rapidly until it is negligible at cone 1. The fire shrinkage is negligible over the range between cones 010 and 03, after which, with the beginning of vitrification, it increases rapidly. They have P.C.E. values usually between cones 3 and 4.

Red-burning Shale. In the case of the red-burning shales, vitrification takes place much earlier, as will be noticed in Figure 17. There is a steady decrease in absorption and the linear firing shrinkage is seldom high. The material above cone 03 becomes very dense. It does not have a very long burning range, due to its low fusion point, below cone 4.

Weathered Shale. The Queenston shale has become weathered in some localities, particularly in the neighbourhood east of Hamilton, producing a very good working clay. This material, owing to much of its fluxes having been removed by weathering action, has a longer range of vitrification than any of the other clays and shales in Ontario. It has consequently been used extensively in the manufacture of better grades of ware, particularly sewer pipe. Deposits are not numerous, however, and it is questionable if any are available today. There is no record of its having been used for the manufacture of roofing-tile, but it would be more suited for this than are the other shales and clays of the province.

Other Shales.

Other kinds of shale occur in Ontario, but their suitability for use in the ceramic industry is questionable. They possess no features that would make them of more value than those shales described above and are, therefore, not mentioned in this report. Information concerning them can be found in the Preliminary Report on the Clay and Shale Deposits of Ontario, J. Keele, Memoir 142, Geological Survey, Canada.

CLAYS

With the exception of the Cretaceous clays of refractory quality that occur in the Moose River basin, outcropping along the Moose River and rivers tributary to it, the known occurrences of stoneless clay in this province are of Pleistocene age. They may be divided into two general classes—marine clays formed at a time when the sea extended up the St. Lawrence and streams tributary to it, and the post-glacial clays that were deposited in glacial lakes as the glaciers receded.

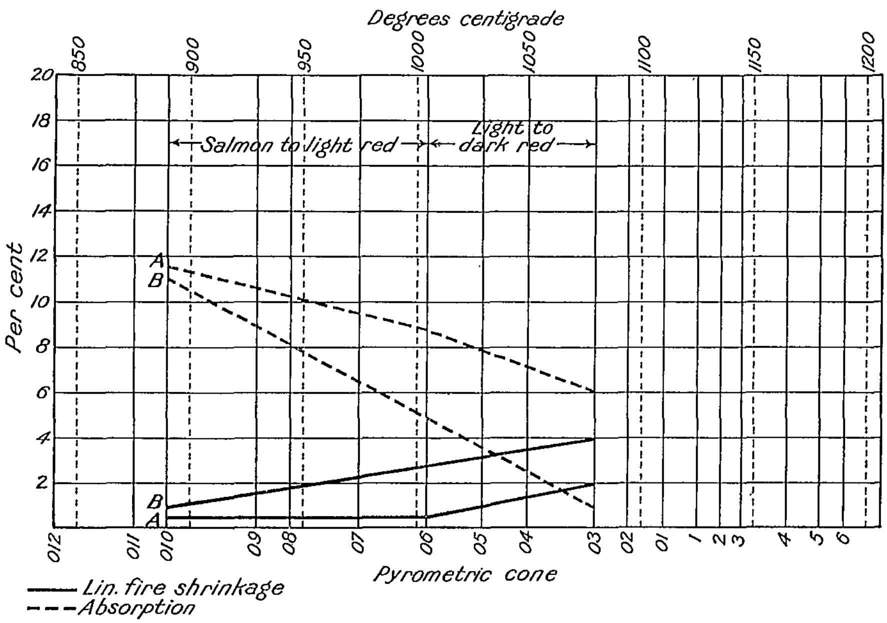

Figure 17. Variation in red-burning Queenston shales.

Marine Clay (Champlain Clay)

Champlain clay is used for the manufacture of soft-mud brick, for which it is most suited. It is used to some extent for the manufacture of stiff-mud products. Its properties are not such as would recommend it for use in the manufacture of roofing-tile.

Extent. Marine clay occurs in abundance in the extreme eastern part of the province between Ottawa and St. Lawrence Rivers. The principal counties underlain by it are Russell, Prescott, and Carleton, though isolated patches are known in Glengarry, Stormont, Dundas, and Grenville Counties.

General Character. By referring to Table I, it will be seen that this clay contains appreciable amounts of fluxes. It burns to red and buff colours, depending upon the lime content, which varies from 2 to 12 per cent. The Champlain clay develops good plasticity, but exhibits poor drying properties, showing anywhere from 7 to 13 per cent linear drying shrinkage. For use in a stiff-plastic consistency, some non-shrinking addition is required.

Burning and Burned Properties. As mentioned above, the Champlain clay burns to buff and red colours. The red-burning varieties begin to vitrify at about cone 03 and vitrification takes place at a fast rate. The buff-burning clay does not begin to vitrify until a higher temperature is reached and vitrification takes place at a faster rate than in the case of the red-burning, once it has commenced.

Post-Glacial Clays

The post-glacial clays are used extensively in Ontario for the production of soft-mud and stiff-mud products, which include brick, hollow tile, drain tile, etc. There is no record of their having been used for the manufacture of roofing-tile, nor would their properties appeal to a manufacturer of that product.

Post-glacial clays are widely distributed over the province of Ontario and are particularly plentiful in the Counties of Hastings, Peterborough, Durham, Victoria, Ontario, Simcoe, and in Muskoka District.

General Characteristics. They develop good plasticity, exhibit good drying properties and burn to buff and red colours, are of low refractoriness and have short burning ranges. As will be seen from Table I, they contain appreciable amounts of the various fluxes. Usually the top of a deposit will burn red while the bottom will burn to a buff; this has been attributed to the extraction of lime by surface waters.

Burning and Burned Properties. In the *red-burning clays* at cone 010, no appreciable amount of burning shrinkage is found; the resulting products have absorptions that vary from 13 to 22 per cent, most ranging in the neighbourhood of 16 per cent.

At cone 06 the burning shrinkage increases to 4 per cent in some clays, but in most it lies below 1 per cent, and the absorption of the burned products varies from 5 to 21 per cent, most approximating to 15 per cent.

At cone 03 the fire shrinkage varies from 1 to 9 per cent, the greater number around 4 per cent, the absorption of the burned products ranging from a negligible amount to 10 per cent, the greater number being below 6 per cent.

The working properties of the *buff-burning clays* are similar to the red-burning. Upon firing, however, the absorption, though higher, begins to decrease at the same temperature as does that of the red product.

From experience it is known that the vitrification ranges of these materials are very short, and like the Champlain clays previously discussed, the buff clays though beginning vitrification at a higher temperature than the red-burning clays, vitrify at a much faster rate, and burn to a poor green colour at vitrifying temperatures.

GENERAL REMARKS

The above conclusions are based upon general ceramic practices up to the present. The suitability of materials may be affected by the developments in the industry from time to time.

Deformation Temperatures of the Orton Pyrometric Cones[1]

Cone No.	20°C. per hour of heating			Cone No.	20°C. per hour of heating		
	Ending point, degrees C.	Ending point, degrees F.	Bending interval, degrees C.		Ending point, degrees C.	Ending point, degrees F.	Bending interval, degrees C.
022.......	585	1,085	45	7.......	1,210	2,210	40
021.......	595	1,103	45	8.......	1,225	2,237	45
020.......	625	1,157	50	9.......	1,250	2,282	65
019.......	630	1,165	30	10.......	1,260	2,300	40
018.......	670	1,238	30	11.......	1,285	2,345	70
017.......	720	1,328	30	12.......	1,310	2,390	80
016.......	735	1,355	35	13.......	1,350	2,462	70
015.......	770	1,418	30	14.......	1,390	2,534	100
014.......	795	1,463	45	15.......	1,410	2,570	85
013.......	825	1,517	45	16.......	1,450	2,642	70
012.......	840	1,544	50	17.......	1,465	2,669	(?) 50–75
011.......	875	1,607	65	18.......	1,485	2,705	90
010.......	890	1,634	30	19.......	1,515	2,759	100
09.......	930	1,706	35	20.......	1,520	2,768	....
08.......	945	1,733	55	23.......	[3]1,580	2,876	[2]30
07.......	975	1,787	35	26.......	1,595	2,903	10
06.......	1,005	1,841	25	27.......	1,605	2,921	15
05.......	1,030	1,886	30	28.......	1,615	2,939	10
04.......	1,050	1,922	40	29.......	1,640	2,984	30
03.......	1,080	1,976	40	30.......	1,650	3,002	25
02.......	1,095	2,003	35	31.......	1,680	3,056	25
01.......	1,110	2,030	50	32.......	1,700	3,092	15
1.......	1,125	2,057	30	33.......	1,745	3,173	30
2.......	1,135	2,075	30	34.......	1,760	3,200	15
3.......	1,145	2,093	30	35.......	1,785	3,245	15
4.......	1,165	2,129	40	36.......	1,810	3,290	25
5.......	1,180	2,156	40	37.......	1,820	3,308	5
6.......	1,190	2,174	40	38.......	1,835	3,335	15

[1] U.S. Bureau of Standards, 1925. [2] Cone 23 to Cone 38 at the rate of 100°C. per hour.
[3] Cone 23 to Cone 38 at the rate of 150°C. per hour.

Bibliography

1. Clays, Occurrences, Properties and Uses, Ries, 3rd Edition, 1927.
2. Modern Tile Making, Alfred B. Searle.
3. Manufacturing of Roofing-Tile, Worcester—Orton, Geological Survey of Ohio, Fourth Series, Bulletin 11, 1910.
4. The Manufacture of Roofing-Tile, A. T. C. Ackworth, John Heywood, Ltd., 20 & 22 Bride Street, London E.C., 4.
5. Bricks and Tiles, Edward Dobson and Alfred B. Searle, Crosby-Lockwood & Sons, Ludgate Hill, 1921.
6. The Porosity of American Roofing-Tile, H. A. Wheeler, American Ceramic Society.
7. Notes on Roofing-Tile Manufacture, Charles Stolp, Trans. American Ceramic Society, Vol. XIII, 1911.
8. Manufacture of Roofing-Tile, British Clayworker, 28, 179, 1919.
9. Some Problems Encountered in Roofing-Tile Manufacture, L. Timmis, The Ceramic Society, Vol. XXVIII, 1928-29, p. 1.
10. Some Different Methods of Fixing Roofing-Tile, Leslie J. Tomlinson, Trans. The Ceramic Society, 1930.
11. Fifteenth Census of the United States, Manufactures, 1929, Industry Series, The Clay Products Industry.
12. The Clay and Shale Deposits of Nova Scotia and Portions of New Brunswick, Ries and Keele, Memoir No. 16E, Geological Survey, Canada, 1911.
13. Clay and Shale Deposits of New Brunswick, J. Keele, Memoir No. 44, Geological Survey, Canada, 1914.
14. Clays and Shales of the Grand Lake Coal Area, New Brunswick, H. Fréchette and J. F. McMahon, Investigations in Ceramics and Road Materials, 1927, Mines Branch, Department of Mines, Canada.
15. Preliminary Report on the Clay and Shale Deposits of the Province of Quebec, J. Keele, Memoir No. 64, No. 52, Geological Series, Geological Survey, Canada, 1915.
16. Preliminary Report on the Clay and Shale Deposits of Ontario, J. Keele, Memoir No. 142, No. 123, Geological Series, Geological Survey, Canada, 1924.

IV

THE PRODUCTION OF SHAPES FROM SOAPSTONE DUST

J. G. Phillips

Soapstone shapes (sawed from the natural block) have been used as linings in certain industrial, low-temperature heat-treating processes and as a lining for ovens to serve as a heat retainer. The thermal properties of soapstone are such that it is particularly suitable for such purposes. The method of producing soapstone shapes by sawing from the natural block is very wasteful. It has been reported that of the soapstone removed from the quarry the amount of waste (unusable fragments as well as sawdust) runs well over 50 per cent.

At the suggestion of the Department of Development of the Canadian Pacific Railway Company, it was decided to carry on an investigation with the purpose of developing a suitable means of bonding soapstone dust, so that shapes, having a strength and other properties comparable to the natural soapstone block, may be produced by a pressing or moulding process. One use in particular for soapstone shapes produced in this manner is as a lining for ovens of kitchen-stoves.

Preliminary Investigations

After reviewing the literature and considering various possible bonding agents, sodium silicate was selected as the most promising. It was decided then to investigate thoroughly the effectiveness of sodium silicate as a bonding agent for powdered soapstone. There being numerous kinds and grades of commercial sodium silicate (all varying in their properties), advice was obtained from an authority connected with the manufacture of sodium silicate as to the best kinds to use for the tests.

Preliminary tests were made with the various kinds of sodium silicate suggested and several were eliminated at the start. The sodium silicates selected are given in the table below:—

Designation — Brand	Na_2O	SiO_2	H_2O	Soda-silica ratio	Baumé
	%	%	%		°
A (liquid)	18·0	35·9	46·1	1 : 2	59·1
B (powdered)	19·4	63·1	17·5	1 : 3·25	....
C (powdered)	27·5	55·0	17·5	1 : 2	....
D (powdered)	33·0	66·0	....	1 : 2	....

Throughout the investigation the strength of bond developed was measured by determining the transverse strength of bars, 1 by 1 by 7 inches, made from the soapstone mixtures in a hydraulic press.

Results of Tests

As it was originally intended that the soapstone shapes should be composed of the dust accumulated in sawing pieces from the natural block, the first tests were made on pieces prepared from a sample of this waste soapstone-dust which had a screen analysis as follows:—

No. 1,	On 20-mesh screen,	0·83%	On 100-mesh	screen,	5·06%
	28 "	0·92	150	"	7·08
	35 "	0·99	200	"	14·00
	48 "	2·0	Through 200	"	64·50
	65 "	3·0			

In this series the effect of pressure and added water (for each pressure) was investigated. The tests with strength results are given in the following table:—

Sodium silicate, %	Added water, %	Pressure in lb. per sq. in.	Heat treatment, 48 hours	Transverse strength, (Modulus of rupture)
8·0 "A"	4·0	250	85° C.	375 lb. per sq. in.
8·0 "A"	6·0	250	85° C.	400 " "
8·0 "A"	8·0	250	85° C.	460 " "
8·0 "A"	4·0	500	85° C.	740 lb. per sq. in.
8·0 "A"	6·0	500	85° C.	750 " "
8·0 "A"	8·0	500	85° C.	920 " "
8·0 "A"	4·0	750	85° C.	800 lb. per sq. in.
8·0 "A"	6·0	750	85° C.	1,100 " "
8·0 "A"	8·0	750	85° C.	910 " "
8·0 "A"	4·0	1,000	85° C.	1,380 lb. per sq. in.
8·0 "A"	6·0	1,000	85° C.	1,400 " "
8·0 "A"	8·0	1,000	85° C.	1,010 " "

It was found that whereas an increase in forming pressure results in increased strength, the rate at which the strength increases for pressures above 500 pounds per square inch is considerably less than for those below 500 pounds. In other words, the slope of the pressure-strength curve flattens at about 500 pounds per square inch.

The effect of added water is shown to be considerable and it is inferred that for each variation in the other factors (pressure, percentage of sodium silicate, and grain size of soapstone) there will be a variation in the optimum percentage of added water.

Increasing the percentage of sodium silicate "A" (the grain size and pressure factors remaining the same) led to the following results:—

Sodium silicate, %	Added water, %	Pressure in lb. per sq. in.	Heat treatment, 48 hours	Transverse strength, (Modulus of rupture)
10 "A"...........................	4·0	500	85° C.	920 lb. per sq. in.
10 "A"...........................	6·0	500	85° C.	1,020 " "
10 "A"...........................	8·0	500	85° C.	1,200 " "
12 "A"...........................	6·0	500	85° C.	1,250 lb. per sq. in.
12 "A"...........................	8·0	500	85° C.	1,410 " "
12 "A"...........................	10·0	500	85° C.	1,240 " "

Using sodium silicate "B", a powdered type, the following results were obtained.

The grain size of the soapstone was the same as in the first series (that given by screen analysis No. 1).

Sodium silicate, %	Added water, %	Pressure in lb. per sq. in.	Heat treatment, 48 hours	Transverse strength, (Modulus of rupture)
6·0 "B".........................	8·0	500	85° C.	720 lb. per sq. in.
6·0 "B".........................	10·0	500	85° C.	830 " "
6·0 "B".........................	12·0	500	85° C.	900 " "
6·0 "B".........................	14·0	500	85° C.	800 " "
8·0 "B".........................	8·0	500	85° C.	800 lb. per sq. in.
8·0 "B".........................	10·0	500	85° C.	940 " "
8·0 "B".........................	12·0	500	85° C.	950 " "
8·0 "B".........................	14·0	500	85° C.	1,020 " "

Sodium silicate "B" being in a powdered state the optimum percentage of added water was found to be much higher than when a liquid brand is used. The maximum strength was developed with the highest percentage of added water. With this pressure (500 pounds per square inch) and soapstone of this screen analysis, 14 per cent of added water was the maximum amount that the mixture (soapstone plus powdered sodium silicate) would hold without water being squeezed from the test piece during pressing. For powdered sodium silicate and soapstone having a screen analysis approximating No. 1 it was considered that 14 per cent of added water was the optimum amount and this percentage of added water was adopted for all cases when a powdered kind of sodium silicate was used.

Increasing the percentage of sodium silicate "B" to 10, with all other factors the same, gave the following:—

Sodium silicate, %	Added water, %	Pressure in lb. per sq. in.	Heat treatment, 48 hours	Transverse strength, (Modulus of rupture)
10 "B"	14	500	85° C.	1,330 lb. per sq. in.

The results obtained by the use of other kinds of sodium silicate are given in the table below.

Sodium silicate, %	Added water, %	Pressure in lb. per sq. in.	Heat treatment, 48 hours	Transverse strength, (Modulus of rupture)
10 "C"	14	500	85° C.	1,500 lb. per sq. in.
10 "D"	14	500	85° C.	1,050 " "

The Effect of Drying Temperatures

In order to ascertain the most strength-yielding conditions of drying, test pieces of each series were given the following drying treatments: (1) 48 hours at 85° C., (2) 48 hours at 110° C., (3) 1 week in air at room temperature, followed by 24 hours at 85° C.

It was found, in general, that nothing was gained by increasing the drying temperature to 110° C., as the test pieces dried at 110° C. showed about the same strength as those dried at 85° C.

In all cases the test pieces dried in air were considerably weaker than those given more rapid drying treatment in the dryer. The very slow drying treatment seemed to permit a segregation of the sodium silicate which was noticeable to the eye in the test piece, and so yielded a much weaker bond.

Pieces from the same batches were also given a humidity drying treatment by maintaining a moisture-saturated atmosphere in the dryer (which was held at 85° C.) for 48 hours, and then gradually reducing the humidity until the pieces were thoroughly dried. This treatment produced no appreciable increase in strength over those dried with no attempt at humidity control.

The Effect of Heat Treatments at Higher Temperatures

The accompanying graph shows the effect of firing soapstone test pieces bonded with the several brands of sodium silicate and fired to the temperatures indicated.

The optimum percentage of added water as determined for the various brands of sodium silicate was used but the other factors, pressure, grain size of sodium silicate and initial drying treatment (48 hours at 85° C.) were the same.

From the graph it is seen that in all cases there is a steady decrease in strength up to and including 700° C. Between 700° C. and 890° C. there is an abrupt and very large increase in strength. This is probably the result of incipient fusion of the sodium silicate.

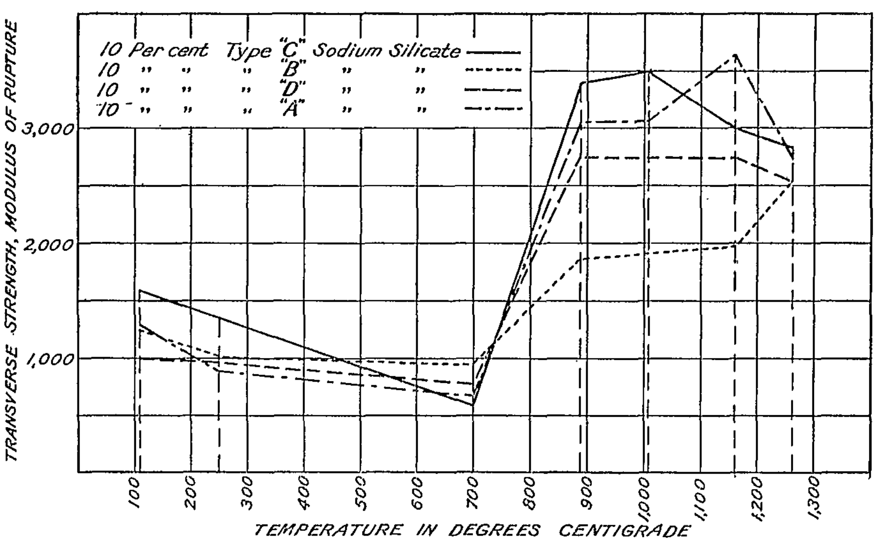

Figure 18.

At 1260° C. there is a decrease in strength in all cases excepting the test pieces bonded with sodium silicate "B" which showed a further increase in strength. The decrease in strength is probably due to the fact that sodium silicate becomes molten at this temperature and the resulting brittleness of the glassy sodium silicate produced a decrease in transverse strength. That the sodium silicate had reached a molten condition at this temperature was further substantiated by the fact that the test pieces exhibited an appreciable sag after having been fired. The test pieces were supported in the kiln by knife edges (at a span of 6 inches) in order to ascertain the degree of sag at this temperature which indicated the degree of fusion of sodium silicate. There was no sag at the firing temperature below 1260° C.

Data on shrinkage and absorption were also taken for the various firing temperatures. They are given below:—

Firing temperature	1		2		3		4	
	Soapstone plus 10% "C"		Soapstone plus 10% "B"		Soapstone plus 10% "D"		Soapstone plus 12% "A"	
	*Shrinkage, %	Absorption, %	*Shrinkage, %	Absorption, %	*Shrinkage, %	Absorption, %	*Shrinkage, %	Absorption, %
700° C.	0·86	19·8	0·86	21·0	0·0	22·0	0·57	21·1
890° C.	2·1	21·5	1·7	21·0	0·86	24·3	1·4	23·6
1005° C.	2·1	22·6	1·7	25·5	0·86	26·0	1·4	23·5
1165° C.	2·1	22·0	1·7	21·3	0·86	27·3	1·4	22·3
1260° C.	2·6	17·5	2·3	17·5	1·4	17·5	2·6	16·6

*This is linear shrinkage and there being no measurable shrinkage in drying, it is the total shrinkage.

Sodium silicate "B" was found to be the most refractory of the kinds investigated. The strength of the trial pieces bonded with it increased up to 1260° C. (while with the other brands a decrease was shown at this firing temperature) and they showed no sag after having been fired to this temperature. Pieces bonded with sodium silicate "B" would withstand temperatures up to 1260° C., whereas with the other kinds it would not be safe to subject pieces bonded with them (using these percentage additions) to temperatures above 1165° C.

The Effect of the Grain Size of Soapstone on the Strength of the Bonded Pieces

Screen Analyses Showing Proportion of Grain Sizes

—	1	2	3	—	1	2	3
	per cent	per cent	per cent		per cent	per cent	per cent
On 28 mesh	12·0	7·75	1·75	On 100 mesh	8·5	9·50	5·06
On 35 mesh	15·0	12·76	0·99	On 150 mesh	8·5	9·05	7·08
On 48 mesh	10·5	10·06	2·0	On 200 mesh	9·0	13·00	14·00
On 65 mesh	8·5	8·55	3·0	Through 200 mesh	27·5	28·00	64·50

Strength Values[1] Obtained

Soapstone Batch No.	Sodium silicate "A", %	Pressure in lb. per sq. in.	Transverse strength, (Modulus of rupture)
1	12	500	2,025
1	10	500	1,950
1	12	250	1,250
1	10	250	910
1	6	250	550
2	12	500	1,700
2	12	250	1,100
3	12	500	1,400

[1] In every case the strength values are given for the optimum percentage of added water.

As the percentage of fine-grained material increases the optimum percentage of added water increases. All other factors being the same, the large effect that a variation in grain size has on the resulting strength value is shown. Even a small difference in the proportion of fines to coarse resulted in a considerable difference in strength. Soapstone batch No. 1 had 46·0 per cent of material larger than 65 mesh as compared to 39·0 per cent in batch No. 2. Test pieces processed identically (with the exception that the optimum percentage of water was used for each case) from the two batches gave transverse strengths of 1250 and 1100 pounds per square inch in pieces formed with a pressure of 250 pounds per square inch, and 2025 and 1700 pounds per square inch in the pieces formed with a pressure of 500 pounds per square inch. With pieces prepared from soapstone batch No. 3, which had only 7·7 per cent of material larger than 65 mesh, and formed with a pressure of 500 pounds per square inch, a transverse strength of 1400 was obtained.

Pieces were also prepared from soapstone composed entirely of fine-grained soapstone. Material was separated into the following grain sizes: (1) 65 mesh to 100 mesh, (2) 100 mesh to 150 mesh, (3) less than 150 mesh. In all three cases a comparatively low strength value was obtained, showing that a composition of uniform grain size is quite unfavourable to strength.

For the greatest strength it is desirable then to have a certain proportion of coarse grains.

Ability of the Bonded Shapes to Resist the Destructive Action of Moisture in Atmosphere

In order to determine whether or not the bonded pieces would be seriously weakened by contact with a very moist atmosphere pieces bonded with several brands of sodium silicate and processed in several different ways were exposed to an atmosphere saturated with moisture at a temperature of about 100°C. for two weeks. At the end of this period the pieces were tested for transverse strength and it was found that in no case was there an appreciable decrease in strength.

CONCLUSIONS

1. By the use of sodium silicate powdered soapstone can be pressed into shapes that will have a strength and durability sufficient to meet any requirements that have been met by shapes sawed from the natural block.

2. A brand of sodium silicate of a type similar to "A" (a liquid brand) is considered the most effective and practical as the bonding agent.

Eight to 10 per cent by weight of liquid sodium silicate (on the basis of dry soapstone) is the optimum percentage addition.

3. In forming, a pressure of no more than 500 pounds per square inch is required.

4. If the grading (according to size), and proportioning of the soapstone grains could be regulated a much stronger shape could be produced.

5. Firing the bonded shape to a temperature of about 900°C. results in a great increase over the strength and durability obtained by simple drying.

The method of bonding soapstone dust with sodium silicate is considered economic and advantageous for the following reasons: (a) larger scale and more rapid production would be enabled, (b) shapes of more uniform size could be produced, (c) waste, both from breakage in sawing and accumulated dust would be eliminated.

V

THE CONTINUATION OF THE INVESTIGATION OF THE TREATMENT OF CLAYS TO OVERCOME DRYING DEFECTS

J. G. Phillips

In previous studies on clays possessing a severe tendency to crack during drying from the plastic state, it was found that the cracking was due to an inherent quality of the clay which did not permit water to flow readily from the interior of the moulded piece to the surface as evaporation took place. The greater the retardation of water flow, the greater was the tendency to crack. Experiment showed that in a normal drying clay, after partial drying, there was only a slight increase in the percentage of water at the interior of the test piece over that at the surface and from the surface to the interior this increase was very nearly uniform. Also it was found that at no time during the drying process was this condition upset, since as water was evaporated at the surface, a steady flow of water from the interior was maintained. In the case of the clays possessing a pronounced tendency to crack, after drying had progressed for a period (to a point where cracking began), determinations showed that there was a large difference between the water content of the surface layers and the interior of the test piece, and in the most extreme cases instead of a gradual increase in water content from the surface to the interior, there were abrupt and large increases a short distance from the surface. In addition it was indicated that the cracking was not due to an abnormally high shrinkage as it was found that some of the clays possessing a severe tendency to crack did not exhibit a high drying shrinkage, and some clays possessing a high shrinkage showed normal drying characteristics. Though a high drying shrinkage can give rise to drying troubles and cause cracking, the tendency to crack caused by shrinkage alone is not nearly so severe and can usually be corrected either by the addition of some non-plastics or by some form of humidity drying process.

The method of comparing clays as regards the inherent property which permits water to flow to the surface during drying has been described in previous reports. The method is indirect but is the most practical way that could be found by which this property could be investigated.

It consists in subjecting a plastic test piece to an arbitrary, moderately rapid drying treatment and allowing the drying to progress to a point where cracking takes place. It had been found that drying at 65°C. for a period of three hours carries the drying process far enough to promote strains and still not have the test piece too badly cracked for the purposes of the test procedure. A core approximately one-half inch in diameter is cut from the partly dried test piece and then beginning at the surface end of the core, successive sections are cut 0·15 of an inch in thickness. These sections are then placed in previously-weighed, stoppered weighing-bottles and the weight taken, after which the stoppers are removed and the clay sections allowed to dry to constant weight at 110°C. The dried weights are then taken, and the percentage moisture present in the various sections can be calculated. The results are then plotted and the shape of the curve indicates the drying characteristics of the clay.

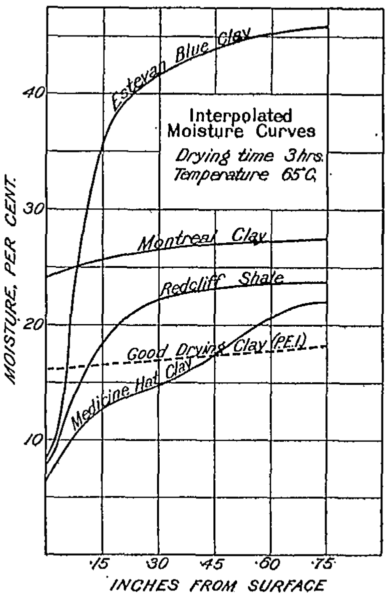

Figure 19

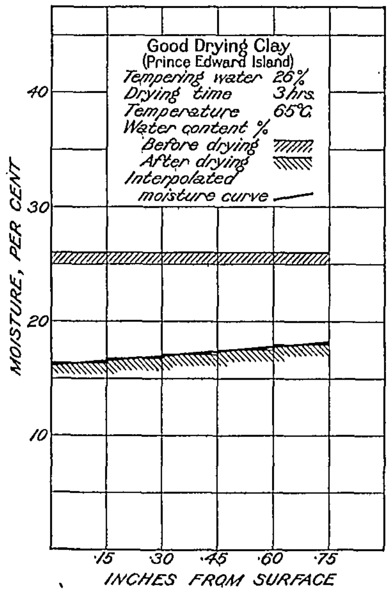

Figure 20

THE CURVES

In Figure 19 curves of several notably bad-drying clays are given. The great contrast between the curve of the normal drying clay and the curves of the Estevan blue clay, the Redcliff shale, and the Medicine Hat clay is shown.

Montreal Clay

The Montreal clay, while requiring much more tempering water gives a curve that differs only slightly from the normal. From a comparison of the curve of the Montreal clay, Figure 21, with the curve of the good drying clay, it would not be expected to exhibit a severe cracking tendency. Actually it does not and, while it presents drying difficulties, the cracking is due chiefly to a high drying shrinkage rather than to retarded water flow to the surface during drying. In this clay there is a slight tendency against an easy moisture movement as is shown by the slightly more rapid rise of the first part of the curve as compared to the portion representing the interior of the test piece. In this case correction of drying troubles could be accomplished either by some means of reducing shrinkage or by some form of humidity drying process. This clay is used industrially for the production of hollow building tile and sawdust is added (about 30 per cent by volume) for the dual purpose of preventing dryer loss and to yield a lightweight unit. As described in a previous report[1]

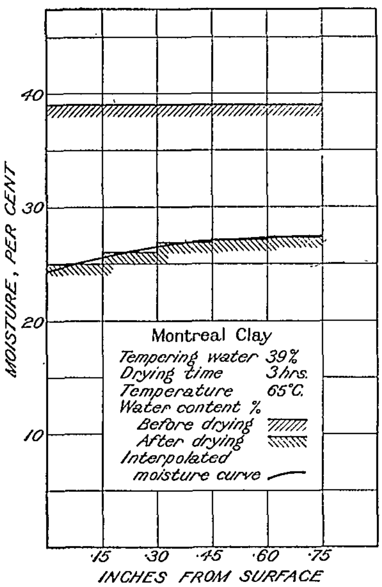

Figure 21

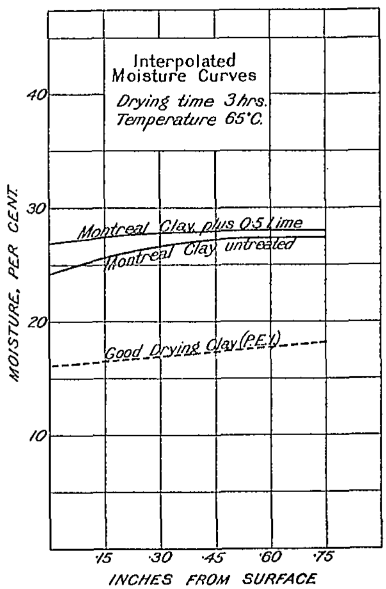

Figure 22

even with the addition of the sawdust there was at times a heavy dryer loss due to cracking, caused by a lack of control of the drying process. With the addition of sawdust the ware could be dried safely if the process was not too rapid. However, at this plant there were not the facilities for accurately controlling the drying rate, with the result that at times drying would be carried on too rapidly and the ware would crack.

In order to afford a greater margin of safety a mild chemical treatment was sought. Experiments proved hydrated lime to be very effective in improving the drying properties of clays and the interpolated moisture curves showed that a 0·5 per cent addition of lime would bring about the desired result. At first a mixture of sodium chloride and lime was suggested. It was later found that the salt was unnecessary. The curves in Figure 22 portray the change effected by lime and show that a 0·5 per cent addition of lime causes the clay to yield a curve closely approaching

[1] Mines Branch Report No. 722, Investigations in Ceramics and Road Materials, 1928-1929, p. 52.

that of a good drying clay. Lime is very effective in opening up the structure of clay bodies, thus making them more permeable to water, but it usually has a harmful effect on fired colour and consequently cannot be used in cases where a good red colour is essential. However, in cases where colour is not of prime importance, for example, in the production of common brick, hollow building tile and drain tile, lime supplies a very effective means of correcting drying troubles of this kind. In the case of the Montreal clay, the required percentage addition being small, little change in the firing properties was produced. There was somewhat of a bleaching effect on the fired colour, but it was not pronounced.

As mentioned above the drying troubles arising from the use of the Montreal clay could be overcome by the introduction of a humidity drying process, or a carefully controlled and mild drying treatment. The installation of humidity drying equipment would have been too costly and, in the dryers that the plant was equipped with, it was impossible to maintain sufficiently accurate control to assure the required mild drying treatment. It was necessary to resort to other means, and a small percentage of lime was found to alter the clay sufficiently so that it could be dried safely under the drying conditions prevailing at this plant.

Estevan Blue Clay

The Estevan blue clay is one that possesses extremely bad drying properties. The degree of its drying defects is shown by the curve—Figure 23 and it is also proven that its drying defects are due to a very high resistance to water-flow during drying. When this clay is subjected to a drying treatment the water at the surface evaporates and the water in the interior (beginning at a point only a very short distance from the surface) is held so tightly that there is almost no water movement toward the surface, with the result that in a very short time the surface becomes bone dry while the interior has retained almost its original water content. Such a condition of course results in an exaggerated case of cracking. The surface layers, as water is evaporated, shrink, and there being practically no shrinkage occurring beneath the surface, it is obvious that a maze of cracks must develop. The final drying shrinkage of this clay is high, but not abnormal, and its drying defects are purely due to its peculiar behaviour with regard to the movement of water to the surface as drying proceeds. Such a clay could not be safely dried commercially, no matter how careful and mild a humidity drying treatment was employed. Also the addition of non-plastics even up to very high percentages has practically no effect. Such a clay can only be rendered dryable from the plastic state (and when processed by the dry-press method it will crack during water-smoking) by either chemical treatment or a preheating treatment.

Figure 24 shows the great improvement resulting from the addition of the two most effective usable coagulating chemicals. Previous work has shown that ferric chloride and hydrochloric acid are by far the most effective agents (within practical limits) in improving the drying properties of clays of this nature. With the curve of the good drying clay as a standard the great improvement effected by additions of ferric chloride and hydrochloric acid is shown. This clay can be rendered dryable by additions of 1·0 per cent of either ferric chloride or hydrochloric acid. Additions of smaller amounts of these chemicals does not bring about sufficient improvement, and more that 1·0 per cent would be superfluous.

This blue clay has good working and firing properties, develops a very good cherry-red colour, and with its cracking tendency counteracted it would supply a means of producing a very good grade of red face brick, something that is quite rare in the Prairie Provinces. The production of stiff-mud face brick from this clay has never been attempted commercially, but in time, as market demand for red face brick increases in the Prairie Provinces, it is considered to have very good possibilities.

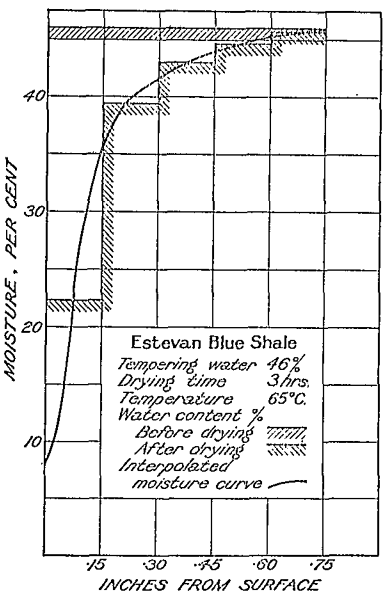

Figure 23

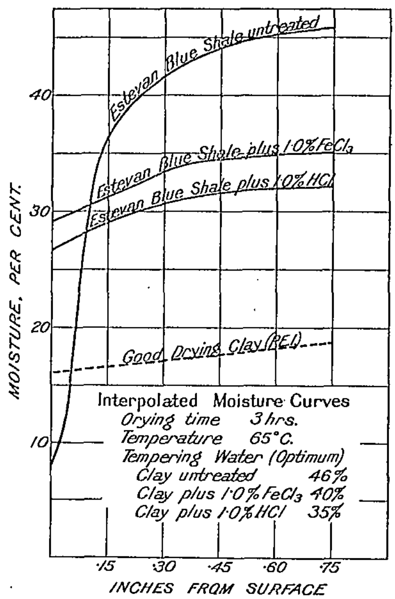

Figure 24

The occurrence of this clay is extensive and abundant. At the pit of the Estevan Coal and Brick Company, which is now called the International Clay Products Company, the section is as follows:

Boulder clay....................................	10 to 20 feet.
Lignite..	8 feet.
Parting clay....................................	2 to 3 feet.
Lignite..	8 inches to 2 feet.
Blue clay.......................................	30 to 40 feet.

Untreated, this clay requires about 46 per cent tempering water, and with regard to working properties it is highly plastic, tough, and sticky. After treatment with 1·0 per cent of either ferric chloride or hydrochloric acid there is an appreciable decrease in stickiness, with a decrease in tempering water to 41·0 per cent when ferric chloride is used and to 35·0 per cent when hydrochloric acid is used.

In the untreated state briquettes made from this clay crack so badly, even when dried extremely slowly, that drying shrinkage measurements are impossible. After treatment the following drying shrinkage results were obtained:—

Treatment	*Linear Drying Shrinkage*
1·0 per cent $FeCl_3$	11·6 per cent
1·0 per cent HCl	10·0 "

This clay fuses at cone 3 (2093°F.) and at a firing temperature of cone 06 (1841°F.) it develops a good clean cherry-red colour and a hard, dense body structure.

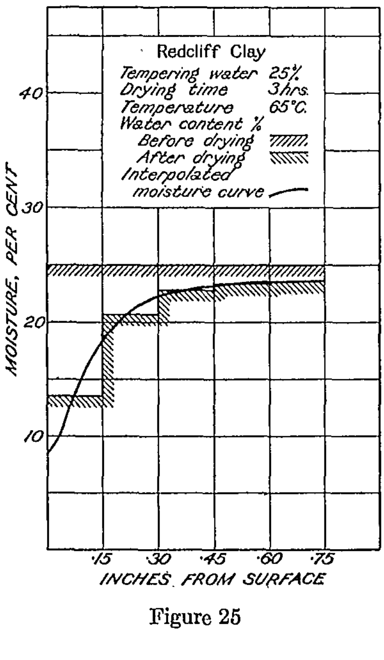

Figure 25

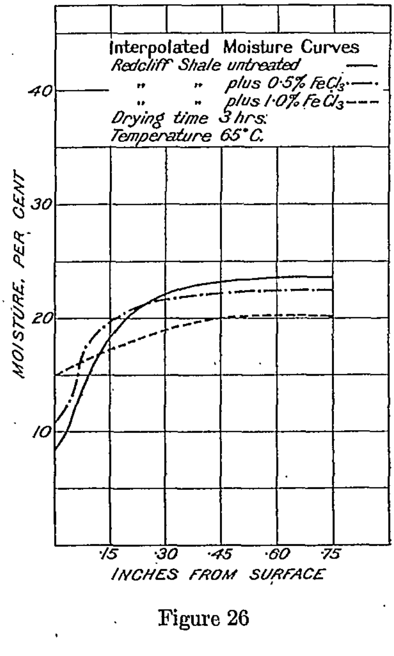

Figure 26

Redcliff Shale

The curve of the Redcliff shale (Figure 25) shows it to be of a similar nature to the Estevan blue shale, although not such an exaggerated case. It possesses an extreme tendency to crack in drying and the cracking is due to the premature drying of the surface layers of the moulded piece caused by the inability of water to move to the surface during drying. This clay does not exhibit a very high drying shrinkage and its cracking tendency is due entirely to its lack of permeability to water. The addition of non-plastics alone produces little improvement even up to the proportion of one to one, and it is not possible to dry this clay safely on a commercial scale, no matter how carefully and slowly the process is carried out, except after either chemical treatment or preheating.

The curves given in Figure 26 show the improvement caused by additions of ferric chloride. Ferric chloride was found to be the most effective corrective agent for this clay, even better than hydrochloric acid, the theory being that the clay contains "buffer" materials that counteract the effect of hydrochloric acid to a greater degree than they do ferric chloride.

For further information concerning this clay and the industrial application of chemical treatment to overcome its drying defects. *See* Mines Branch Report No. 722, Investigations in Ceramics and Road Materials, 1928-1929, p. 46.

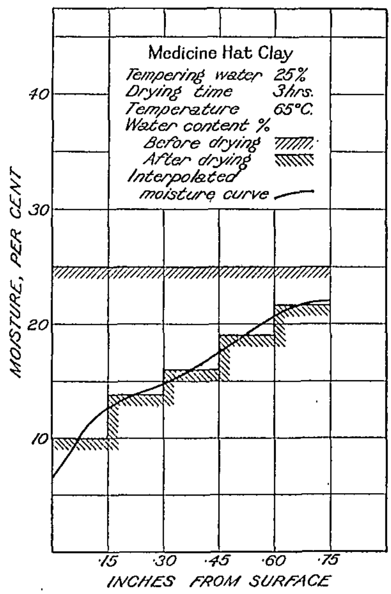

Figure 27

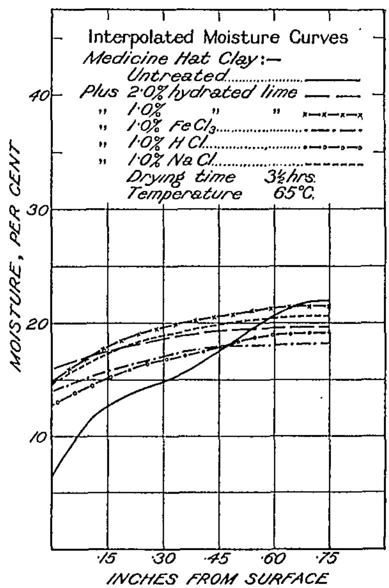

Figure 28

Figure 27 shows the curve of the clay taken from the pit of the Medicine Hat Brick Company, located at Medicine Hat, Alberta. The clay is taken from a high bank and is composed of a heterogeneous mixture of a rather sandy, soft clay and fragments of soft shale with gumbo-like properties. Both the soft clay and the shale present serious drying difficulties, the shale possessing an extreme tendency to crack. The manner of winning yields a mixture of the soft clay and shale with a considerable quantity of sand that is intentionally incorporated from various bands running through the bank. The sample taken for investigation represents the mixture that is used in the plant. This company produces common brick, hollow building tile, drain tile and a small amount of stiff-mud, wire-cut, face brick. The drying of the ware has presented serious troubles. This clay mixture does not have so severe a tendency to crack as the Estevan blue clay or the Redcliff shale, but unless ware from it is dried with extreme care with an accurately controlled humidity treatment, serious cracking will result, and even then there is likely to be a considerable dryer loss.

The curve of this clay shows it to be somewhat different from the Estevan blue clay and the Redcliff shale. There is still a large difference between the water content of the surface section and the interior, but the increase is more gradual, and the abrupt change is lacking. The curve shows that in this clay, during drying, there is a movement of water to the surface but not fast enough to approach equilibrium with the rate of evaporation at the surface. If this clay could be dried at an extremely slow rate it would not crack. This, however, is not considered commercially feasible, especially in a progressive tunnel-type dryer. Although it would be possible, by resorting to very long drying periods, to get some of the ware safely through the dryers, there would always be a rather high dryer loss.

Figure 28 shows the effect of various chemicals on this clay. It can be seen that both lime and ferric chloride produce great improvement. For the production of face brick from this clay the addition of 1·0 per cent ferric chloride is recommended. For the production of common ware between 1·0 and 2·0 per cent lime should be added. Lime cannot be used in the production of face brick as it is detrimental to the fired colour.

It was found that lime, when added to this clay, causes a decrease in both the green and fired strength of the ware. In order to ascertain the amount of this decrease and whether it would be sufficient to make the use of lime objectionable, tests were conducted on mixtures of lime with the Medicine Hat clay. The results obtained are given in the following table.

Added lime, %	Drying temperature	Firing temperature	Transverse strength, (Modulus of rupture)
0·0	65° C. (149° F.)	Unfired	1,100 lb. per sq. in.
0·0	65° C. (149° F.)	Cone 06 (1841° F.)	1,550 " "
0·0	65° C. (149° F.)	Cone 03 (1976° F.)	2,300 " "
1·0	65° C. (149° F.)	Unfired	800 lb. per sq. in.
1·0	65° C. (149° F.)	Cone 06 (1841° F.)	1,100 " "
1·0	65° C. (149° F.)	Cone 03 (1976° F.)	1,800 " "
2·0	65° C. (149° F.)	Unfired	700 lb. per sq. in.
2·0	65° C. (149° F.)	Cone 06 (1841° F.)	1,000 " "
2·0	65° C. (149° F.)	Cone 03 (1976° F.)	1,500 " "

The results show that lime produces an appreciable decrease in both the green and fired strength but the decrease is not considered excessive when the lime is added in percentages up to 2·0.

At the Medalta Potteries of Medicine Hat, Alberta, a clay of about the same composition and nature as that worked by the Medicine Hat Brick Company is now being used for the production of red flower pots.

The ability to correct the drying defects of the Medicine Hat clay by chemical treatment has made possible the production of a good grade of flower pots from this clay. The clay fires to a good red colour, and by the addition of approximately 0·5 per cent ferric chloride, the pots are safely dried with very little cracking. As the pots are dried in air at room temperature a smaller percentage of ferric chloride is required than if they were given a more rapid drying treatment. Without the ferric chloride addition the pots crack severely even when dried at this slow rate. This clay contains a considerable quantity of soluble salts which cause the formation of a discolouring scum on the ware. In addition to rendering the clay safely dryable, ferric chloride prevents the appearance of this scum on the fired ware, and this reduces the amount of barium carbonate that would otherwise be required. A very small percentage of barium carbonate is also added to insure the prevention of scum.

SUMMARY

As regards drying properties, clays may be divided into three classes:—

1. Clays possessing satisfactory drying properties and that can be dried at a moderately rapid rate without cracking.

2. Clays that exhibit a high drying shrinkage, which causes cracks to develop if not dried carefully.

3. Clays that possess an inherent quality that resists the flow of water to the surface during drying, that are characterized by severe cracking when dried at a moderately rapid rate, and that cannot be safely dried (within practical limits) except after treatment.

The method described in this report has been found quite useful in determining to which class a clay belongs as regards its drying properties, and in the case of clays belonging to the third class (those owing their drying defects to low permeability to water) it supplies a means of measuring the degree to which a clay may possess this inherent defect.

A number of notably bad-drying clays have been investigated in this manner, classified according to drying properties, and in the case of those clays requiring it, the kind and amount of treatment necessary to correct the defect has been determined.

Chemical treatment can be applied not only to render certain clays dryable that otherwise could not be dried commercially without cracking, but in less severe cases, when a long and careful drying process is required to avoid a heavy dryer loss, it provides quite a profitable alternative in that it will (1) reduce considerably the required drying time, thereby increasing capacity and saving in fuel; (2) reduce costs by substantially reducing dryer loss; (3) improve the quality of the ware.

VI

ROAD MATERIALS IN QUEBEC, 1930 AND 1931

R. H. Picher

The investigation on road materials in the province of Quebec, undertaken in 1929, was continued in 1930 and completed during the field season of 1931. The work consisted in making a detailed survey of gravel deposits for the purpose of ascertaining their quality as road material, through examining the gravels as they lie in the bank, noting results obtained where used in road construction, and testing of samples taken from the deposits. The extensive use of gravel during the last few years on all kinds of roads afforded a good opportunity of studying the wearing qualities of many types of gravel in actual service and under various traffic conditions.

All the settled parts of the province, with the exception of the northern districts of Témiscamingue, Abitibi, Rouyn, and Lake St. John, have been covered by the investigation. The information gathered in the field work of 1930 and 1931 appears in this volume, while the results of the field work of 1929 have been incorporated in a previous report.[1]

Mortar tests, the results of which appear in Tables III and VI, were made on samples collected primarily for testing as road materials. The samples, therefore, do not necessarily represent those parts of the deposits carrying the highest grade concrete aggregate.

Observations on the effect of weathering on the quality of gravels were made in the report of the Division for 1928 and 1929 and are not repeated here.

1930

AREA COVERED

The territory covered by the investigation in 1930 is roughly triangular in outline and comprises that part of the province lying between the St. Lawrence River and the International boundary. The field work was started at the west end of this area, in Huntingdon County, and it was planned to proceed as far east as where the field work of the previous year ended, that is, on a line running approximately from Levis to Waterloo. On account of lack of time, part of the area, including Yamaska, Nicolet, and portions of Lotbinière, Arthabaska and a corner of Drummond Counties, could not be examined in detail. Over most of the area left out, however, gravel is very scarce, according to information received from local highway officials, and outside of the southeast corner of Drummond and the adjacent part of Arthabaska Counties, no important deposits are known to occur.

One hundred and forty deposits were examined, of which seventy are described in this report, and eighty samples were collected for testing.

[1] Investigation in Ceramics and Road Materials, 1928-1929, Mines Branch, Department of Mines, No. 722.

Service Tests

The considerable mileage of roads surfaced with gravel during the last few years afforded a good opportunity to observe, under actual service conditions, the results obtained with gravel from a large number of deposits and to compare the relative merits of the gravels. In connection with the study of road conditions, reliable information could be obtained in most cases regarding the source of the gravel, age of the surface, and maintenance. The results of these observations will be found in the description of the individual deposits, and in a shorter form in the remarks of Table II. Very dry weather prevailed during much of the field work, so that roads inspected were more dusty than under normal weather conditions. This condition applied to all but the Counties of Drummond, Shefford, Brome and the eastern part of Bagot, where the work was done under normal fall weather conditions.

Huntingdon County

Gravel is fairly common throughout the greater part of the county, but nearly all important deposits lie within two to three miles of the International border. It is exceedingly scarce around the town of Huntingdon and in that part of the county bordering Lake St. Francis. As a result of the large amount of road work done in the last few years, all known deposits have been developed to some extent, so that the qualities of the various gravels could be readily observed and compared. Some of the many excavations are now abandoned, either on account of the gravel being exhausted or grading into inferior material. Following is a short description of the more important deposits:—

Dundee Township

1. *Lot 20, Concession I; Mrs. Watson.* The deposit has been excavated to its full depth over an area of 3,900 square yards and a maximum depth of bank of 13 feet. The gravel is coarse and bouldery but otherwise well graded. It is used for surfacing local roads, all material over 1½ inches in size being screened out and piled in the pit. The road between lots 20 and 21 along which the deposit is situated has been surfaced with this material, which is well compacted, and the road surface is almost as smooth as rolled broken stone, but only moderately durable. The gravel deposit lies alongside of a ridge of glacial drift, which is seen exposed at one place in the gravel pit bank. The amount of gravel available is conservatively estimated at four times the amount already taken out, or about 35,000 cubic yards.

2. *Lot 18, Concession IV; C. Smallman.* About 12,000 cubic yards have been excavated from this deposit, and, for the most part, shipped across the International border for road purposes. This excavation and several other smaller ones in the same deposit are no longer worked for road purposes, on account of too much sand being found. There is much fresh, coarse sand, suitable as cement-concrete aggregate, exposed in the larger excavation. The deposit is very large, but is mostly sand, with probably very little road gravel left.

3. *Lot 18, Concession IV; Mrs. M. Holden.* The gravel looks much like No. 1, as regards grading and coarsenesss, and about as good, judging from results obtained in surfacing a short stretch of the road between lots 17 and 18. Very little has been used so far, and the size of the deposit is at least 10,000 cubic yards, including overburden, which is said to be thick in places. This estimate does not take into account the southern end of the deposit, which lies past the International border.

Godmanchester Township

5. *Lot 61, Concession V, Part owned by Canadian National Railways, and part owned by Godmanchester Township.* The township pit has been excavated over an area of 17,000 square yards and is over 50,000 cubic yards in size; the railway pit is at least four times as large. The coarser gravel is now about exhausted, but there is a large amount of fine sandy gravel left in the bottom of the two excavations, which were not dug deeper on account of underground water. Most of the material taken out of the township pit has been used in surfacing local township roads and very good results have been obtained. The roads were inspected after prolonged dry weather and were very smooth, but rather dusty.

6. *Lot 55, Concession IV; J. S. Leblanc.* About 3,000 cubic yards of gravel has been taken out of this deposit, which is in the form of a terrace lying along the lower northwest slope of a large ridge of glacial drift, and used in surfacing a stretch of the road between Concessions III and IV. The gravel, although high in sand, compacts readily to a smooth surface, but is rather dusty when dry. It is not known whether the whole terrace is gravel, if so, there would be well over 10,000 cubic yards. The gravel is covered with 2 to 4 feet of fine sand, which should not be a serious obstacle in the development of the deposit, because the steep slope of the terrace would make it possible to open a large side-hill cut with a high face and thus minimize the relative cost of stripping.

8. *Lot 42, Concession IV; S. Barry.* Gravel has been excavated over an area of 4,800 square yards and to the full depth of the deposit, which averages 9 feet. Most of it was used on the main highway leading to Huntingdon and other local roads. It is a course and bouldery, well-graded though soft gravel, which consolidates readily on the road, wears smoothly, but is not durable and makes a dusty surface when dry. The excavation now measures over 14,000 cubic yards. Further development would necessitate the removal of several farm buildings, including two houses. The amount of gravel that can be obtained is unknown. The deposit forms part of a long, narrow ridge of glacial drift.

9. *Lot 47, Concession II; U. Hurteau.* Nearly all gravel of size and coarseness suitable for road purposes has been removed from the deposit. A large excavation extending over 10,000 square yards shows almost entirely sand and gravelly sand, of which there is a large amount, and which makes a good cement-concrete aggregate. Gravel for road purposes is now being hauled from deposit No. 10.

10. *Lot 47, Concession I; O. Caza.* The deposit forms a pocket in a low ridge of sand. The gravel is well graded, but soft and interstratified with much sand. It is used in maintenance work on a stretch of the

nearby provincial highway, which will soon be covered with surface-treated macadam. Gravel is exceedingly scarce in this part of the county.

11. *Lots 25, 26, Concession II; A. Mainville and J. Brunet.* A narrow and shallow pit opened along the crest of a ridge of glacial drift now extends over 5,000 square yards. The drift carries a larger proportion of stone beneath the crest than in the remainder of the ridge, and looks like very coarse and bouldery gravel. The material is dug by gasoline shovel, and is crushed and screened with a portable plant. The product is used in the surfacing of unimproved roads, and in the maintenance of local gravel roads. including a stretch of provincial road. It is a durable road material, which wears evenly, but is very dusty when dry. Although gravel is almost totally lacking in this part of the county, there is an abundant supply of boulders available from the many ridges of glacial drift. This deposit appears to be richer in stone than the average glacial drift of the district.

Elgin Township

13. *Lot 9, Concession II; F. Brown.* Over 15,000 cubic yards has been taken from this deposit, which forms a flat-topped ridge, with a maximum depth of gravel of 15 feet. The gravel is generally fine and sandy, but outside of the weathered zone in the upper part of the pit bank, the sand is very coarse. In the upper bank, the gravel is less sandy, but the sand finer, and the material as a whole not so well graded and softer. Much poorly graded gravel including layers of fine sand and silt, is seen in that part of the bank that runs parallel to the direction of the ridge, and is assumed to be on the edge of the deposit. The larger part of the gravel taken out has been used in surfacing local roads. Stretches of the road between Concessions I and II recently surfaced were found on inspection to be in excellent condition, whereas older stretches were decidedly dusty when dry.

Hinchinbrook Township

18. *Lot 38, Concession III; R. Arthur.* The larger part of the gravel used now, in the improvement of the provincial highway leading to Huntingdon, is hauled from this deposit. The excavation measures over 4,000 cubic yards, and although the deposit does not average more than 7 feet in depth, it covers a fairly large area. The gravel is remarkably uniform in grading, and carries on the average 50 per cent of very coarse sand. The material compacts firmly on the road and is reasonably free from dust.

Franklin Township

21. *Lot 27, Concession II; E. Roy.* The excavation extends over an area of 9,000 square yards and to a depth of 5 feet, which is the full depth of the deposit. The gravel is well graded, uniform in coarseness, and carries a high proportion of sand, all of which is very coarse. Slightly finer and much less sandy gravel than the average is seen in that part of the pit nearer to the north edge of the deposit. The gravel is extensively used on local roads and on the county road leading to St. Chrysostôme in Chateauguay County. The gravel works best on clay subsoils, but

does not consolidate so firmly and produces much dust on light sandy soils, although sections with sandy subsoil which had been surfaced and travelled over for some time were found in good condition and quite smooth. With reference to the dust it is well to mention that the roads were inspected after a prolonged spell of dry weather. The gravel from the north end of the deposit is particularly well graded for road purposes.

Havelock Township

24. *Lot 81, Concession II; C. B. Edwards.* In an excavation partly talus-covered, the exposed part shows rusty gravel, which varies much in coarseness, but is on the whole very coarse and bouldery, and carries a very small amount of sand, some streaks being almost entirely free from sand. With the larger stones screened out, the gravel gives good results in road work and compacts quite readily. It has been used for the improvement of the road between Covey Hill and Vicar, the surface of which is now in excellent condition. The deposit forms a terrace that can be traced for miles, but the gravel is probably not all of proper size and grading for road purposes.

Hemmingford Township

26. *Lot 106, Concession III; R. Hayden.* The deposit lies along the southeast slope of a ridge of glacial drift. In the lower slope, the gravel is very uniform in size and grading, carries about the right proportion of sand, but the sand is too fine. Towards the crest of the ridge, the gravel merges into irregularly sorted material, made up largely of sand and boulders. The gravel has been extensively used in surfacing the road from Hemmingford to the International border and a section of the provincial highway between Hemmingford and Corbin. Although only moderately durable, the gravel makes a smooth and firm surface. It is said to take a long time to compact properly under traffic, undoubtedly owing to the fineness of the sand.

27. *Lot 178, Concession V.* The deposit forms a small, flat-topped ridge and has a maximum depth of 10 feet. The gravel is slightly bouldery, coarse, well graded, but somewhat soft on account of partial weathering. Several local roads have been surfaced with the material, which is now being used in the improvement of a section of the new provincial highway east of Hemmingford. It compacts readily and smoothly on the road, but is not very durable and produces much dust under traffic, when in a dry state. Excavating the deposit to its full extent would necessitate the removal of a house with farm buildings.

Beauharnois County

Very little gravel has been used in the improvement of roads, mostly owing to the fact that it is very scarce within the boundary of this county. Surface-treated macadam is the type of paving used in the improvement of the larger mileage of main roads, including also some secondary roads.

Sample 30 (Tables I and II) was taken from a small, newly-opened pit in a ridge of glacial drift. These ridges, although fairly common, are not so numerous as in Huntingdon County. Glacial drift resembles gravel in character, but makes a less desirable road material, on account of being poorly graded and carrying much fine sand, silt and clay. Where the proportion of pebbles and medium-size boulders is high, the drift can be turned into a fair road-surfacing material, suitable for light-trafficked roads, through crushing and screening. Such is the case with deposit No. 11 described above. Although the proportion of stone in that part of deposit 30 where the sample was taken is quite high, it cannot be considered as representing the average for the deposit, on account of the very small face exposed in the pit. As far as known, the amount of drift material used for surfacing roads in the county is negligible.

Chateauguay County

Gravel is totally wanting over the greater part of the county. The only important deposits are found grouped together in the northeast end, close to the Laprairie County border. A few small deposits scattered over the southern part of the county are now becoming rapidly exhausted. The deposits described below are all, apart from No. 32, situated in the northeastern end of the county.

32. *Three-quarters of a mile west of Cairnside; D. Greig.* The deposit lies along the southeast margin of a wide, flat-topped ridge of glacial drift. Gravel, which varies much in coarseness but is generally coarse, bouldery and sandy, is seen exposed for a distance of over 150 yards in a long, narrow pit. Patches of bouldery drift are also exposed, and it seems that the excavation has reached beyond the gravel into the drift, so that the gravel is now almost exhausted. The road from Cairnside to Brysonville is now being surfaced with gravel from this deposit. The material consolidates readily and makes a smooth but dusty road surface.

Another larger excavation in the same ridge one mile and a quarter to the northeast, shows almost entirely very bouldery drift. Boulders are for the most part hard sandstone, and if crushed to proper size would make a fair aggregate for any type of pavement except waterbound macadam. The amount of boulders is practically unlimited.

35. *Three miles south of Ste. Philomène; T. Thibert.* The deposit is largely medium-fine sand. A 30-foot face in a large excavation, dug in the steep slope of a bluff, shows occasional large streaks or pockets of very coarse gravel running irregularly through the sand. Outside of the gravel streaks, the sand is very uniform in coarseness and grading, and has been extensively used on local clay roads. The sand is rather fine, but is found to compact very quickly and form a smooth, hard surface, which, however, has not the durability of a gravel road. Older stretches of these sand-clay roads are found to be dusty when dry.

36. *One and three-quarter miles southeast of Ste. Philomène; E. Vallée.* The deposit occupies the southeast slope of a flat-topped knoll or ridge of glacial drift. The gravel is generally very coarse and in places bouldery, but coarseness varies a great deal from place to place. The finer gravel is as a rule the more regularly graded, on account of not carrying so much fine sand as the coarser material. Crushing and screening the gravel is strongly

advisable in order to obtain a uniform product. As regards composition and soundness of pebbles, it is much the same as deposit No. 37 (see sample No. 37, Tables I and II). About 4,200 cubic yards have been taken out and the amount available is unknown but in all probability large.

37. *Two miles southeast of Ste. Philomène; Canadian National Railway.* A very large excavation in the form of a side-hill cut, 2,300 feet in length, shows gravel that is more uniform in coarseness and grading than the other local deposits. Although there is much coarse and bouldery gravel and also much sandy material exposed in the long pit face, most of the coarser and more bouldery gravel is concentrated in the central part of the deposit, from where the gravel decreases regularly and gradually in coarseness towards both ends. The material is used only for ballast purposes.

38. *One and a half miles southeast of Ste. Philomène; A. Bannan.* A 30-foot excavation in the steep northwest slope of a flat-topped ridge shows material that is much the same as in deposit No. 35, that is, sand with occasional streaks or pockets of fine to very coarse gravel. The sand, though not so uniform in size, is on the whole coarser than in deposit No. 35. The deposit lies along the northwest slope of a wide, flat-topped ridge; most of it is probably glacial drift.

Deposits Nos. 35, 36, 37 and 38 form part of a wide, flat-topped ridge of glacial drift which trends in a northeast-southwest direction and has a length of several miles.

Laprairie County

The few small gravel deposits occurring in the county are now all exhausted, and gravel for road purposes has to be brought in from outside. Very little gravel is now used on the main roads, some of which are part of the more important provincial arteries.

Napierville County

A large gravel area between St. Rémi and St. Michel, including deposits Nos. 39 and 40, has been extensively worked in the past for railroad ballast and road purposes. Although there is still a considerable amount of material available, most of what is left is very sandy. In the remainder of the county, the few deposits found are of small size and are becoming rapidly exhausted. All gravels are very sandy, and some of them hold much weathered or soft pebbles, but they all consolidate readily and form smooth surfaces on the clay soils that cover the greater part of the county. Some stretches resemble more sand-clay than gravel surfaces. The gravel roads were examined during a spell of dry weather, and outside of recently surfaced stretches, were found quite dusty.

The following are the more important deposits:—

39. *One and a quarter miles southwest of St. Michel; T. Bisson.* This small and shallow deposit lies at the south end of a large gravel area which runs for several miles northwards and includes No. 40. Gravel does not form a continuous deposit over that distance, but occurs as a series of streaks or pockets through a large sand area. In addition to Nos. 39

and 40, there are several other excavations, including a railway pit, which are now abandoned on account of the material turning too sandy. Gravel from deposit No. 39 is also very sandy, but well graded, holds much coarse sand, and consolidates readily on local clay roads.

40. *One mile east of St. Rémi; O. Robert, F. Houle.* The deposit rises but a few feet above the level of a sand area in which it is included. Very sandy gravel is seen throughout a large excavation extending over 8,000 square yards and dug to the full depth of the deposit, which averages 9 feet. The gravel is used on local roads and in the adjacent part of Laprairie County. Good results are obtained on roads with clay subsoil. Stretches which have been gravelled for at least one year are dusty when dry.

42. *Douglasburg; R. Béchard.* About 4,800 cubic yards of gravel have been taken out of this deposit, which is now more than half exhausted. The gravel holds from 15 to 30 per cent of friable pebbles and is very sandy, the proportion of sand being nowhere less than two-thirds. Best results are obtained on clay roads, where it compacts readily to a smooth and firm surface, which is more of a sand-clay type of road surface, and does not possess the wearing quality of the average gravel road. A very good example of this type of surface can be observed on a stretch of provincial highway a short distance west of Douglasburg.

43. *One and a quarter miles west of Napierville; E. Cyr, N. Fortin.* A large excavation, 15,400 cubic yards in size, cuts through the whole width and depth of a gravel deposit occupying the southwest end of a ridge. The amount excavated represents probably less than half of the size of the deposit, for the entire recovery of which it would be necessary to remove a house and farm buildings. The gravel carries on the average 60 per cent sand, and although rather sandy it is used with good results on clay soils in the making of road surfaces of sand-clay type. After a certain time on the road, the gravel becomes very dusty during dry weather: this is apparently due not so much to the high proportion of sand as to its fineness.

St. Johns County

The few deposits found in the county have been worked extensively for road gravel and most of them are now more than half exhausted. The only deposits of comparatively large size are found west of Odelltown, southwest of St. Blaise and southwest of St. Johns. The few other deposits are of small size and are situated at the south end of the county. A considerable amount of gravel has been taken from the large deposit west of Odelltown both for railway ballast and road purposes. There is still much gravel available, but it is very coarse and has to be crushed and screened to make it a satisfactory road-surfacing material. Several shallow deposits of fine and sandy gravel southwest of St. Blaise are included in a large sand tract several miles in length. Several large pits have been opened in the gravel, but an approximate estimate of the amount available is difficult to make on account of sand covering the whole area. Two fairly large deposits southwest of St. Johns hold soft gravel. One may be considered as exhausted, since what is left is weathered, soft and sandy. The other is now more than half exhausted, the remainder being rapidly absorbed in road building. It is rather soft for the most part, but holds large streaks of fresh, clean, well graded material.

46. *Two miles west of Odelltown; Parish of St. Bernard.* Over 15,000 cubic yards have been excavated for road purposes, mostly in the last few years, and previous to this a much larger amount had been taken out for railway ballast. The gravel is coarse and holds a low proportion of sand and boulders. It is now crushed and screened for road-surfacing purposes in a portable plant erected in the pit. The crushed material is extensively used in surfacing local roads. The gravel surfaces are very firm and smooth, but were very dusty when inspected during a spell of dry weather. A stretch of road treated with calcium chloride was found exempt from dust. The greater part of the dust is not the result of wear on the road, but is in the gravel screenings before they are laid on the road as a finishing course.

50. *Two miles west of St. Valentin; C. Deneault.* The deposit holds gravel that is much weathered and very soft. It is irregularly graded, but due to its softness compacts readily on the road. It is suitable at best for roads carrying a light traffic.

51. *Two and three-quarter miles southwest of St. Blaise; B. Breault.* Several large but shallow deposits of sandy gravel are found included in a large sand area trending north-south from the village of St. Blaise to a short distance south of No. 51. Some of the deposits are now exhausted or not worked any longer on account of being too sandy. In No. 51, the gravel is fresh, hard and, although carrying a great deal of sand, is well graded and the sand mostly coarse. It has been extensively used for road purposes: it consolidates firmly, wears evenly and is durable.

53. *Two miles southwest of St. Blaise; A. Gagnon.* The deposit occurs in the same large sand area as No. 51, and the gravel possesses much of the road-making qualities of No. 51. Most of the gravel used on local roads comes from one of these two deposits.

55. *Three and a half miles southwest of St. Johns; A. Tremblay, A. Roulier.* Close upon 20,000 cubic yards of gravel has been excavated, which is more than half the size of the whole deposit. Most of the gravel exposed in three large excavations is partly weathered, soft, irregularly graded, coarse, and sandy. It carries a large proportion of coarse pebbles and fine sand, but not enough medium-size material. One of the pits dug at the south end of the deposit shows in places thick streaks of gravel that is much fresher and better graded than the average. The streaks lie under 3 feet of overburden, whereas the average thickness of overburden for the whole deposit is not over 2 feet. Outside of the better graded material, which is sold solely as cement gravel, the larger part of the gravel excavated is used for road work. For this purpose the material is crushed and screened in a portable plant erected at the pits. On account of the softness of the gravel, there is much dust produced in the process of crushing, and for this reason the screenings (material passing $\frac{1}{4}$-inch screen) are considered as useless and thrown away. The crushed and screened gravel is now used in maintenance work on a section of the provincial highway between St. Johns and Napierville that is treated with

calcium chloride as dust preventive. The gravel wears fast and is not considered of good quality for main highways. It is intended to resurface this highway in the near future with surface-treated macadam, for which purpose there is plenty of good, crushed quarry rock available near the city of St. Johns.

Chambly County

The only gravel occurring in the county is found in the slopes of Mount St. Bruno. A considerable amount of gravelly sand covers the lower, southern slope of the hill, but it is not coarse enough to be considered of good quality for road-surfacing purposes. Coarse gravel is found higher up the slope, and although not covering such a large area as the finer material of the lower slope, it is known to be in large amount. One deposit has been extensively worked in the southeast slope of the hill.

56. *One-half mile north of St. Bruno; E. Goyer.* A pit has recently been opened in gravelly sand, lying under 3 feet of sand. The gravelly sand carries about 25 per cent pebbles in the more gravelly phase, and not more than 10 per cent as pit average. The pit is in the lower south slope of Mount St. Bruno, and according to information gathered from several land owners, the gravelly sand probably underlies a considerable area in the lower south slope, but is everywhere concealed under a thick blanket of fine sand. The material, as judged by that part exposed in pit 56, is much too sandy for road purposes.

57. *One and a quarter miles west of St. Basile; F. H. Clergue.* The deposit, which is an old gravel beach, lies in the middle southeast slope of Mount St. Bruno and a short distance from a provincial highway that skirts the flank of the hill. The gravel exposed in a large excavation 20 feet in maximum depth is rusty, very hard, coarse, and bouldery and carries but a small amount of sand. As regards size of constituents, it is made up on the average of 10 per cent boulders, 65 per cent pebbles and 25 per cent sand. Boulders are for the most part 6 inches in size and sand is very coarse. About 95 per cent of boulders and pebbles are composed of fine-grained, fresh, and very hard trap rock[1]. Nearly all gravel excavated, 43,000 cubic yards, has been absorbed in road work and it is thought that there is a larger amount still available in the deposit. On the road the gravel consolidates firmly and is durable, but does not make so smooth a surface as do finer and softer gravels. Smoothness is attained by applying to the surface a thin course of finer material.

Verchères and Richelieu Counties

The few gravel deposits found within the two counties are small in size and are now almost completely exhausted.

Iberville County

There are several large deposits of sandy gravel in the north and northeast part of the county, but elsewhere gravel is scarce. All deposits have been extensively worked, either for road or for cement gravel. Most

[1] This type of rock is exposed over a considerable area in the west flank of Mount St. Bruno, where there is a quarry operated for the production of crushed stone, a description of which is given elsewhere in this report

of the gravel used for concrete works in the city of St. Johns comes from the several deposits of the north end of the county. The length of haul to St. Johns is approximately 6 miles. With the exception of one deposit, the gravels are rather too sandy for good results in road surfacing.

60. *Two miles northeast of St. Alexandre; J. Breault.* A large sand area that trends in an approximate north-south direction for a distance of over 6 miles, includes several deposits of very sandy gravel, carrying on the average not more than 25 per cent pebbles. No. 60, which is the more southerly, is slightly less sandy, but more weathered and softer, than the others. It carries on the average 25 to 30 per cent pebbles, over half of which are weathered or soft. A section of the road leading to Iberville, and shorter stretches of other local roads, have been surfaced with gravel from deposit No. 60. Although carrying much fine sand, the gravel compacts satisfactorily and wears evenly but would probably not stand too heavy traffic, because a large proportion of the pebbles crumble readily. It is found satisfactory on local clay roads carrying a very light traffic. The roads were inspected during a period of dry weather and were quite dusty, in fact more dusty, but in far better condition than the unsurfaced sections.

63. *One mile northeast of St. Grégoire; E. Tetreau.* The material is more properly gravelly sand than gravel, as it does not carry on the average more than 20 per cent pebbles. Although very sandy, it is well graded and uniform in coarseness throughout that part exposed in a large excavation, 5,500 square yards in extent. On the road it does not compact readily, and is probably not durable, but improves earth roads considerably. South of Tetreau's pit there is a much larger excavation, now all covered with talus and from which gravel was hauled in the past for railway ballast. The deposit forms a wide terrace occupying the lower south slope of Mount Johnson. The gravel or gravelly sand lies under 2 to 4 feet of fine sand.

64. *One and one-quarter miles northeast of St. Grégoire; U. Benoit.* The deposit lies in the lower south slope of Mount Johnson, but at a higher level and in steeper ground than No. 63. The material is largely gravelly sand carrying not more than 25 per cent pebbles on the average, but coarseness varies and large streaks of properly graded, road gravel are not uncommon. On account of the great depth of the deposit, very fresh material is available. Most of the sand and gravel taken out now is used as aggregate in concrete works. A large number of essexite blocks or boulders, some over 5 feet in diameter, interfere with development work. These blocks are largely confined to the upper part of the deposit.

65. *Two and one-quarter miles northwest of St. Grégoire; E. Metras; Department of Highways.* Although large sections are very sandy, the deposit carries coarser and better graded road gravel than any other large deposit of the county. A considerable amount of road gravel was taken out at one time, as judged by the size of the several excavations, the larger one measuring over 100,000 cubic yards. There is a stationary crushing and screening plant erected in the main pit, with drag shovel, steel cable and steel mast resting on concrete foundations. The plant has been idle for some time and is in need of repairs. The deposit is

flat-lying, rather shallow but covers a large area. The very large amount of material still available is quite probably more sandy than what has been already taken out.

Missisquoi County

Gravels are fairly common in the southern half of the county and scarce in the northern half, particularly so in the northwest corner, around the town of Farnham. While all gravels are well graded as regards size of constituents, most of them have poor wearing qualities on account of being weathered and soft. The pebbles crumble readily under traffic and the road surface soon becomes dusty or muddy. In the eastern part of the county, where the land is more hilly, the deposits are deeper and the gravels fresher and of much better road-making qualities than those of the western part. The muddy and somewhat slippery condition observed on old gravel roads when wet is due to the large proportion of slate pebbles found in all deposits. The fresher gravels of the eastern part of the county, although not entirely exempt from this defect, are much less seriously affected than the weathered gravels.

Stanbridge Township

68. *Lot 6, Concession VII; A. A. Coderre.* Between Bedford and the International border, there are several deposits of gravel of about the same character as No. 68 here described. The gravel is well graded and uniform as regards coarseness, but very soft, even when fresh. It compacts readily on the road and stands well under very light traffic but wears fast under a moderate amount of traffic. Its use has been discontinued on main roads.

69. *Lot 19, Concession VI, Stanbridge; P. Clouatre.* Very coarse and bouldery gravel is exposed in a large excavation extending over 5,700 square yards. The pit was originally opened in finer gravel and has been gradually extended into coarser and more bouldery material. Whereas a well graded, uniform product could be obtained by screening out the larger stones, it would be suitable only for roads carrying very light traffic, as it carries a high amount of soft and friable pebbles. Old gravel-road surfaces are very dusty.

St. Armand Parish

71. *Two miles southeast of Frelighsburg; B. Wilson.* The deposit forms a steep-sloped, round knoll in which a side-hill cut, up to 30 feet in height, shows fresh, well graded, sandy gravel carrying on the average 50 to 60 per cent coarse sand. The gravel is only moderately hard and durable, even where free from weathering. On local roads, which carry very light traffic, it compacts to a smooth surface which wears evenly.

Dunham Township

72. *Lot 3, Concession X; G. Barnes.* The gravel is very similar to No. 71 as regards regularity of grading, but more weathered and much softer.

74. *Lot 28, Concession V; Municipality of Cowansville.* The deposit lies in the bank of Yamaska River, and forms a flat-topped ridge, the slopes of which are thickly covered with clay. An excavation has been opened

along the crest of the ridge, where the overburden is thinner, and shows fresh, well graded, coarse gravelly sand, carrying on the average not more than 25 per cent pebbles. The gravel is too fine and sandy for good results in road works, but makes a very good aggregate in concrete. All the gravel taken from the deposit is used in municipal works in Cowansville.

75. *Lot 28, Concession VI; Department of Highways.* The deposit occupies the slope of a steep bluff, facing the Yamaska River, and can be traced more or less continuously as far as No. 74, three-quarters of a mile to the southeast. Fresh, clean, well graded gravel is exposed in a large side-hill excavation 600 feet in length and 40 feet in maximum depth. Although coarseness varies in places, it is on the whole uniform, taking into consideration the very large section exposed. It is a medium-coarse gravel carrying on the average 50 per cent coarse sand. The gravel consolidates readily and firmly on the road, forming a smooth surface which wears evenly. It holds a large proportion of slate pebbles, and for that reason old gravel-road surfaces are slightly muddy when in a wet state. It is without doubt the best road gravel of the county, though not so durable as some gravels found in other counties. It is extensively used in road improvement and is hauled for miles in all directions for that purpose. The gravel makes also a very good aggregate in concrete.

Rouville and St. Hyacinthe Counties

A considerable amount of gravel or, more properly, gravelly sand is found in large, sand benches at the foot and south side of Mount Yamaska, Mount Rougemont and Mount St. Hilaire, in Rouville County. Beaches of coarse gravel are also known to occur in the slopes of the three hills, but the amount of gravel excavated in these beach deposits so far has been very small. Outside of these three areas, gravel is found in a large, narrow ridge of glacial drift in the southeast corner of the county. In the remainder of Rouville and in St. Hyacinthe gravel is totally lacking.

The gravels from the large sand benches at the foot of Mount Yamaska, Mount Rougemont and Mount St. Hilaire are all very hard but vary a great deal in coarseness. Although most of them are poorly graded and very sandy, there are also large streaks of well graded material. Divergent results have been obtained in road surfacing, depending not only on the character of the material used but also on the type of road subsoil. For example, fine sandy gravels give generally indifferent results on the sand roads in the immediate vicinity of the deposits, but prove quite satisfactory on the clay roads farther away from the hills.

76. *One and a quarter miles south of Canrobert; A. Mercure.* The deposit occupies part of the east slope of a long ridge of glacial drift, and carries gravel that is generally fine and sandy near the surface, and coarse and rather bouldery in depth. A large excavation 5,000 square yards in area has been opened in the slope of the ridge. At one end the gravel in the lower part was found too coarse and bouldery and was left in place. The gravel has been extensively used for road making, as outside of this ridge there is no other gravel for miles around. It contains a large amount of

friable limestone or calcareous slate pebbles, wears fast, and becomes quite dusty. On roads carrying a very light traffic, good and smooth surfaces have been built with the material.

77. *Two and a half miles east of Abbotsford; C. Ball.* The deposit forms a long narrow ridge which is part of a wide sand bench stretching southeast from the foot of Mount Yamaska. There has been a considerable amount of material excavated for various purposes, as attested by the size of several pits, either in the ridge proper or in the sand bench. The gravel in the ridge varies much in coarseness within short distances. In Ball's pit thin layers of sandy gravel alternate regularly with thicker layers of coarse and rather bouldery gravel, so that on the whole the grading is fairly uniform. While the bulk of the gravel finds a ready market as concrete aggregate in the town of Granby, much well graded, road gravel is obtained from a large section of the pit bank by screening out the larger stones. This part of the bank shows less sandy and coarser gravel than the average. About 4 feet of worthless sand or gravelly sand has to be removed from the top. Below that depth the material is fresh and carries but a very small amount of soft pebbles.

79. *Three-quarters of a mile west of Mont St. Hilaire; A. Guertin.* The deposit is mostly coarse sand, with not more than 15 per cent pebbles. The material is only moderately hard, and compacts firmly to a smooth surface on clay roads carrying very light traffic. It is much too sandy to produce durable results.

Bagot County

Gravels are very common throughout the county, with the exception of the western end. The larger deposits are found grouped together in four different areas: east of St. Dominique, east and west of St. Liboire, north of Acton Vale, and northeast of St. Nazaire. A number of smaller deposits are scattered in the remainder of the county. Along the western border of the county gravels are almost totally lacking. The St. Dominique deposits have been extensively worked for road gravel to take care not only of local roads but also roads in parts of Shefford and St. Hyacinthe Counties. A considerable amount of cement gravel from these deposits is also hauled to St. Hyacinthe. The other deposits found elsewhere in the county have been worked intermittently for road gravel, with the exception of one of the St. Nazaire deposits that was excavated exclusively for railway ballast. The St. Nazaire deposits have not been examined in detail.

From the road-material standpoint the Acton Vale gravels have proven the more durable and the less dusty. Good road surfaces have been built with the St. Dominique and St. Liboire gravels, but their lack of durability has necessitated renewal at relatively frequent intervals on the more travelled roads. It is true that some of the highways surfaced with gravel from the St. Dominique deposits carry a fairly heavy traffic.

82. *Two miles southeast of St. Dominique; F. X. Breault.* Pits Nos. 82 and 83 are in the same large, flat-lying deposit, which averages 9 feet in depth. Pit No. 82, which extends over an area of 40,000 square yards, cuts away the central part of over one-half of the deposit. Although there is a considerable amount of material left on the edges, most of it is either

very sandy or very coarse, and little is used at present. Sample No. 82 was taken from regular-size gravel exposed only in a small section of the large pit bank. The character of the gravel is much the same as that exposed in pit No. 83, which is situated in the other half of the deposit.

83. *Two miles southeast of St. Dominique; A. Lebeau.* The pit, which lies alongside of No. 82, is over 10,000 square yards in area. The gravel is generally soft, coarse, and sandy, a large proportion of the sand being fine. It consolidates readily on the road, makes a smooth surface, but wears rather fast and is dusty. Sections treated with calcium chloride are almost entirely free from dust. For concrete work, care is taken to use only the fresh and not too sandy gravel. Although the amount available can not be estimated, it is probably very large.

84. *Two and a half miles east of St. Dominique; M. Deslandes.* Pits Nos. 84 and 85 lie alongside of each other in the same deposit, which forms a ridge trending northwest-southeast. The depth of gravel along the crest of the ridge is generally over 25 feet. In pit No. 84, the gravel is generally of medium coarseness, but rather high in fine sand, with an occasional layer of sand. Although on the whole soft and sandy, the gravel in the lower bank is fresher, less sandy and better graded than in the upper bank. As road material it compares with Nos. 82 and 83, but the greater depth of the deposit makes it possible to use fresher and less friable gravel.

85. *Two and a half miles east of St. Dominique; A. Dubreuil.* In the northwest end of the deposit is a large excavation close to 11,000 square yards in extent. The gravel varies in coarseness along the pit face and in depth, but is generally medium-coarse and sandy in the upper 7 to 8 feet, and much coarser and less sandy farther down. Where the gravel is deemed too coarse, it is left in place, so that the depth of the pit runs irregularly from 5 up to 25 feet. Some layers of the lower gravel hold a low proportion of sand, whereas others are just as sandy as the upper gravel. As regards grading and composition, it is about the same as Nos. 82, 83, and 84, but on account of the greater depth, the gravel is fresher and less friable on the average than Nos. 82 and 83. It is at the best only a moderately durable, road material, which makes a smooth but dusty surface. Some layers in the lower part of the deposit contain gravel that is particularly well graded for use as concrete aggregate.

86. *One and a half miles south of St. Liboire; J. Rodier.* A large excavation over 10,000 square yards in area cuts through the full width, and half of the length, of a ridge-like deposit, averaging 15 feet in depth. The gravel, which is coarse in the upper part of the deposit, turns gradually finer in depth. The proportion of sand varies from 40 per cent near the surface to 90 per cent near the bottom. The gravel is well-graded but carries an excess of fine sand and is soft. On the road it consolidates readily, makes a smooth and even surface, but wears fast and is dusty.

87. *One and a half miles southeast of St. Liboire; A. Desmarais.* The deposit lies in the southwest slope of a ridge of glacial drift trending in a northwest-southeast direction, and has a maximum depth of 13 feet in that part of the pit nearer the crest of the ridge. The gravel, fine and sandy near the edge of the ridge, turns gradually coarser and less sandy

towards the crest. It is well graded but soft. On the road a large proportion of the pebbles crumble readily under traffic and the smooth road-surface wears fast and is dusty. As road material it much resembles No. 86.

90. *One and a half miles northwest of St. Liboire; H. Montmarquette.* The deposit occupies the east edge of a slight elevation composed partly, if not mostly, of glacial drift. A pit opened along the east edge has a maximum depth of 13 feet, which is about the greatest depth of the gravel. The gravel is medium coarse, with a rather high percentage of sand, a large part of which is fine. Apart from turning gradually finer in depth, it is uniform in coarseness. It is of about the same character and gives the same results in road surfacing as Nos. 86 and 87.

Acton Township

95. *Lot 33, Concession VI; H. Guérin, J. St. Amand.* The deposit forms a flat-topped ridge, in which two excavations, 6 and 7 feet in depth respectively, have been opened side by side, on two different properties. The excavated gravel has been almost entirely absorbed in road construction and maintenance, and has given good results. It is a fairly hard, medium-coarse, well graded gravel, which compacts firmly on the road and wears well.

Two other deposits of similarly graded, though somewhat softer gravel are found on lot 34 of the same concession, and lots 32 and 33, of Concession V.

97. *Lot 29, Concession VI; H. Champagne.* The deposit lies on top of a wide, high, rocky ridge. It was originally covered with 10 to 15 feet of sand, which, since the beginning of cultivation, has been gradually blown towards the east, under the influence of the prevailing winds. At many places the gravel is now bare of drifting sand. A small shallow pit has been dug into the gravel, which is fresh, well graded, and carries from 40 to 65 per cent sand, mostly very coarse. It is a good road gravel, but little has been used for that purpose up to the present. Due to its almost complete freedom from weathering, it makes a particularly desirable concrete aggregate. According to the owner, the deposit was found to have a maximum depth of over 20 feet through test pits dug by the Canadian Pacific Railway Company, and which are now entirely refilled. An area of about 10 acres has been freed of its overlying sand, which has been blown away farther east.

Brome County

The hilly character of the greater part of this county makes it impracticable to haul gravel from far afield, so that all developed deposits are found along or close to some public road. Gravels are relatively common throughout the northeastern part of the county but scarce elsewhere, particularly so in the southwestern part. Most of the gravels are well graded as regards size of constituents, but because of their high content of soft pebbles, can be considered of but fair quality at best. A few deposits contain gravel, which is also either very sandy or irregularly graded. Good road-surfacing gravel was found in only three deposits, one at Gilman, another one 2 miles east of Knowlton, and a third one 3 miles south of Eastman. The latter has been included in the 1929 report under No. 375.[1]

The most common defect of the gravels is that they wear fast under traffic, requiring frequent renewal of the road surface. River gravel from the bed and flats of Missisquoi River, available at low water level between Glen Sutton and Dunkin, is found to have more lasting qualities than the local bank gravel.

Brome Township

107. *Lot 4, Concession II; W. MacNeil.* The 25-foot face of a side-hill excavation in the steep slope of a knoll shows mostly sand. At one end of the pit bank there is a large streak of well graded gravel varying from very fine to medium coarse. Sample 107 (Tables I and II) represents the coarser phase. The deposit forms three knolls in line, covering, according to the owner, an area of 4 acres and measuring 40 feet in average height. The deposit holds probably much more sand than gravel. Between here and the International border, over 11 miles to the south, gravel is exceedingly scarce, and a number of knolls have been prospected for gravel but found to be made up largely of sand. One such knoll in the town of Sutton has been extensively worked for concrete sand.

108. *Lot 7, Concession II; Department of Highways.* The deposit forms a large steep knoll in the slope of which a deep side-hill excavation has exposed gravel that varies a great deal in coarseness, but large streaks of uniformly graded, fresh gravel are also common. Good results in road surfacing are attained with the gravel. It consolidates firmly to a smooth surface that wears well under traffic. As a matter of fact, it is one of the very few gravels of the county which possesses lasting qualities. The amount of gravel available is large. Several other knolls a few hundred feet to the east are gravelly on surface. All knolls aggregate in size well over 100,000 cubic yards.

109. *Lot 10, Concession VI; J. C. Soles.* Coarse, uniformly well graded gravel is exposed in a pit cutting through almost the whole width of a ridge. When the larger stones are screened out, the gravel makes a fair road material. It is on the average better graded than No. 108, but softer and not so durable.

Bolton Township

115. *Lot 11, Concession I; M. Hunt.* A side-hill excavation, 30 feet in greatest depth, has been opened in the steep slope of a knoll or ridge, and exposed well graded, fine gravel carrying 50 to 60 per cent of sand, mostly very coarse. While coarseness is not uniform throughout the exposed part, the material is on the whole regularly graded as regards size of particles, with the exception of a thick sand layer, which runs more or less continuously all along the bank at middle height. The gravel has been used for the surfacing of several local roads with good results. Although somewhat fine and sandy, it is durable and may be considered one of the best gravels found in the county. The deep excavation makes it possible to get fresh material that makes a good aggregate in concrete work.

[1] Investigations in Ceramics and Road Materials, 1928–1929, Mines Branch, Department of Mines, No. 722.

Shefford County

Gravel deposits are fairly evenly distributed throughout the county, but nowhere very common, except around Waterloo and Lawrenceville. The gravel from nearly all deposits is well graded as regards coarseness, but only moderately durable as road material. The larger Lawrenceville deposit, some of the Waterloo deposits and a smaller deposit near Roxton Falls are those only from which gravel with good wearing qualities has been obtained. A few small and shallow deposits from around Granby hold a large amount of soft shale or slate, which crumbles very readily under traffic and causes the road surface to become muddy when wet. The use of this gravel is now confined to unimportant roads.

One large deposit of good road gravel, situated almost on the Brome County border, south of Waterloo, has been described as deposit No. 371 in the 1929 report[1] and is not included in the following list.

Milton Township

120. *Lot 17, Concession II; G. Messier.* A large shallow excavation, 3 to 8 feet in depth and covering over 5,500 square yards, has been opened in a flat-lying, gravel deposit trending in a north-south direction. Bedrock is exposed in the bottom and centre of the pit, 3 to 4 feet below the surface, and is probably close to the surface over the larger part of the deposit, but deeper digging has been prevented by the presence of occasional large boulders or blocks of the same nature as the underlying bedrock. The greatest depth, 8 feet, is at the north end of the pit, where a test pit is said by owner to have been dug to an additional depth of 7 feet, without reaching the bottom of the deposit. The gravel varies in coarseness, but is on the average fairly coarse and well graded. It consolidates readily on the road, and builds a smooth surface. It wears rather fast, but is better in that respect than other local gravels. The poor results obtained in the mortar test (Table III) are due to impurities in the gravel near the surface, where the sample was taken.

121. *Lot 2, Concession I; S. Paul.* The deposit occupies a depression between rock ledges that limit it three-quarters of the way around. It has been excavated to a depth of 12 feet, which is not the full depth of the deposit, but a deeper excavation would be difficult to drain. The gravel is well graded and varies from coarse to fine, the coarser phase being found at about middle height. It gives about the same results as No. 120 as road-surfacing material, being only moderately durable. The much better results obtained in the mortar test (Table III) as compared with No. 120, are not due to a difference in grading but to the fact that sample No. 121 was taken at a depth of 6 to 10 feet, in fresher and cleaner gravel than is usually found nearer the surface.

Roxton Township

125. *Lot 16, Concession X; N. Raymond.* The deposit is 6 to 8 feet in depth and lies in level ground on the top and edge of a steep clay or boulder-clay bluff facing the river. The gravel has been excavated down to the underlying clay over an area of 3,600 square yards, which is about

[1] Investigation in Ceramics and Road Materials, 1928-1929, Mines Branch, Department of Mines, No. 722.

one-quarter of the extent of the deposit. The gravel is well graded and fairly uniform in size throughout, and remarkably fresh, considering its shallow depth. It has given good service on local roads, where it consolidates firmly and makes a hard and lasting surface.

Shefford Township

129. *Lot 23, Concession VII; Shefford, Mrs. C. McLaughlin.* The deposit is in the shape of a straight, steep-sloped ridge trending in a north-south direction along a river bank. A pit at the north end cuts through the crest and half way down both slopes of the ridge, and shows gravel that varies much in coarseness, including large streaks of well graded road gravel, but also much coarse and bouldery gravel and a large streak of sand. The sand is all confined to the lower east slope and can be left in place without interfering with the development work, but the coarser gravel lies in the upper part of the ridge and can not be left in place without sacrificing good gravel lying underneath. Very little gravel has been used lately for road purposes.

132. *Lot 27, Concession VIII; Department of Highways.* A side-hill excavation with a face up to 25 feet in height, in the steep slope of a flat-topped ridge, shows well graded, fine gravel carrying about 50 per cent very coarse sand, topped with 4 to 8 feet of bouldery, weathered gravel. The ridge measures approximately 50,000 cubic yards. According to information received from the road patrolman, the same gravel was encountered in two test pits dug near the crest of the ridge, a short distance back of the pit face, with 2 and 8 feet respectively of bouldery material lying on top of the better graded gravel. In the pit face, outside of the upper bouldery zone, the gravel is comparatively free from weathering, yet rather soft. A stretch of the Waterloo-Richmond highway surfaced with this gravel was found in good condition. The gravel packs down solidly to a smooth surface, but wears rather fast.

Stukely Township

133. *Lot 16, Concession IX; Z. Gervais.* Near Lawrenceville, there is a very large gravel deposit in the form of a straight, steep-sloped ridge 40 feet in height and measuring over 200,000 cubic yards. According to the road patrolman, gravel underlies a large area outside of the ridge proper, including the greater part of the village. A big excavation, not dug to the bottom of the deposit, cuts through the full height and width of the ridge over a distance of 100 yards. Although the large pit face shows much variation in coarseness of the material, the greater part of the gravel exposed is well graded and of the proper size for road purposes. Good and durable road surfaces have been built with it. It is not so uniform in grading as some other deposits, but is the most durable gravel found in the county. On account of the great depth and steep slope of the ridge, fresh gravel holding very little friable material can be obtained in large amount with comparatively little stripping.

Drummond County

The present investigation covered all but the southeastern corner of the county.

Gravels are of common occurrence only in the southern part of the county. Elsewhere they are very scarce, particularly so in that part bordering Yamaska County to the northwest. All the more important deposits have been examined and are described below, with the exception of two deposits near Ulverton that were examined in 1929, and have been included in the report for that year, under Nos. 368 and 369.[1]

Durham Township

138. *Lot 11, Concession X; Bonner Sand and Ballast Co., 1434 St. Catherine St. West, Montreal.* The deposit occurs as a steep-sloped knoll, part of which has been completely levelled by a large excavation dug to its base. The pit face, up to 80 feet in height in the centre, shows gravel that is generally coarse, but varies from place to place.

The pit is connected by spur to the Canadian National railway. The gravel is dug by steam shovel and either loaded directly into railway cars or crushed and screened in a stationary plant erected at the pit with storage bins, from which the gravel is loaded by gravity into railway cars. The product is sold as railway ballast, road gravel, or concrete aggregate. The gravel as it comes from the bank is sufficiently free from fine sand or large stones to make a suitable railway ballast without crushing and screening. On account of the great depth, the gravel is clean and almost free from weathered or friable particles. Sample No. 138 was taken primarily for submission to the abrasion test, and does not by any means represent the average run of the large pit bank.

139. *Lot 10, Concession IX; E. Reed; J. E. Mitchell.* A round pit, 35 feet in maximum depth, dug in the upper half of a steep-sloped, round knoll, shows mostly clean, coarse sand, interstratified with a few thin layers of gravelly sand. Close to the bottom, there is a thick layer of well graded gravel, which is about the right coarseness for road purposes. Outside of this layer, the material is undoubtedly too fine for road work but makes a very good concrete aggregate, as it is everywhere very clean and coarse below the weathered zone.

140. *Lots 14, 15, Concession IX; Dominion Sand and Stone Co., 865 Roy Street East, Montreal.* A very large excavation opened in the steep slope of a knoll over 100 feet in height is worked in three different levels. A standard gauge track on each level is linked to a spur line that connects the pit with the Canadian National railway at South Durham. The pit was originally opened in sand and for years worked solely as a sand pit. As the excavation proceeded farther into the knoll, gravel layers were found and now the pit is operated for both sand and gravel. The material is dug by steam shovel and loaded directly into railway cars. For gravel, a slanting screen of the proper mesh is fitted on top of the car, to separate the oversize which rolls down to the side of the track and is wasted. Although there is considerably more sand than gravel exposed in the large

[1] Investigations in Ceramics and Road Materials, 1928–1929, Mines Branch, Department of Mines, No. 722.

pit face, gravel layers have gradually increased in size and number during the last few years, and it is now planned to erect in the fall or early spring a crushing and screening plant. Both sand and gravel are clean and almost free from weathered or soft particles. The product is sold for concrete aggregate, road gravel and railway ballast. Moulding sand is also obtained from a large streak of fine sand lying deep in the bank. Sample No. 140 was taken primarily for submission to the abrasion test and is not representative of the average run of the gravel; sample No. 140a is from a coarse phase of the sand.

141. *Lot 24, Concession I; T. Labonté.* A large side-hill excavation dug in the upper slope of a steep bluff or knoll, shows considerably more sand than gravel. The pit floor slants slightly inwards, following the surface of glacial drift that underlies the gravel. In the lower half of the pit face, which has a maximum height of 23 feet in its central part, there are several layers of fine gravel carrying 60 to 75 per cent coarse sand, but by far the larger part of the bank is sand, fine and silty in the upper third, coarse under. The amount of gravel sufficiently coarse for road purposes is small and is used entirely for maintenance work. Although there is much clean and coarse sand, of excellent quality as concrete aggregate, it is topped by several feet of fine, in places silty, sand that is not so good.

Wickham Township

142. *Lot 15, Concession IX; A. Lepage.* In a flat-lying deposit, said by the local road patrolman to have an area of about 15 acres, a large pit averaging 7½ feet in depth has been dug to the bottom of the deposit. The gravel is well graded, uniform in size, and carries about 60 per cent sand, mostly coarse. Although partly weathered, it does not contain too much friable material and is fairly durable. A section of the road leading to Acton Vale, and other local roads have been covered with the gravel and apart from being rather dusty when in a dry state are in good condition.

Wendover Township

143. *Lot 1, Concession VIII; A. Lafond.* The deposit forms a small, flat ridge overlying glacial drift and averaging 5 feet in depth. The gravel is well graded, uniform in coarseness and carries from 30 to 50 per cent of very coarse sand. About 80 per cent of the pebbles are flat slate or shale. The gravel consolidates readily on the road and builds a firm and remarkably smooth surface, but wears rather fast under a moderate amount of traffic and old roads are muddy when in a wet state. There are several other small, shallow deposits of similar gravel. One much larger deposit was extensively worked years ago for railway ballast. It is now exhausted, or what little left is very sandy.

144. *Lot 1, Concession XIII; Department of Highways.* Fairly well graded, fine, sandy gravel is seen in a large, shallow excavation extending over 20,000 square yards and dug to the bottom of the deposit, which averages 4½ feet in thickness. The gravel is partly weathered, yet fairly hard, and wears well under light traffic. The deposit forms a large, flat-topped ridge, part of which includes bouldery or poorly graded material, so that the amount of good road gravel is unknown and probably small.

STONE QUARRIES

Two stone quarries operated for the production of crushed stone, one in Chambly County and the other in Bagot County, have been made part of the present investigation. Other quarries are worked for the same purpose in the area examined, but these have already been considered and included in previous investigations and reports.

The quarry in Chambly County is situated in the west flank of Mount St. Bruno, and is owned and operated by St. Bruno Quarry Company, Limited, 6418 St. Hubert Street, Montreal. The stone quarried is a bluish black, fine-grained camptonite, better known in the trade under the general term of trap rock. An electrically-operated, crushing and screening plant installed at the quarry site, produces seven different sizes of stone, from 3 inches down to screenings. The stone is stored in bins, from which it is loaded by gravity into motor trucks. The company owns about 34 acres of land. A sample collected from the quarry tested as follows:—

Specific gravity	2·78
Weight, lb. per cu. ft.	173
Water absorption, lb. per cu. ft.	0·12
Percentage of wear	1·70
French coefficient of wear	23·5
Hardness	18·2
Toughness	20

Judged by the results of the tests, the stone is a high-grade road-metal that can be safely used in all types of pavements and under all traffic conditions. Pebbles from gravel deposit No. 57, which is described in this report, are almost entirely made up of this kind of stone.

The quarry in Bagot County is situated in the steep slope of a hill, a short distance southeast of the town of Acton Vale, and is owned and operated by Kennedy Construction Company, 407 McGill Street, Montreal. The stone is light bluish grey, fine- grained, massive limestone, more or less metamorphosed into marble. A stationary, crushing and screening plant erected at the quarry site is designed to produce all the commercial sizes of crushed stone required. The quarry is connected by spur to the Canadian National railway and the stone is loaded directly by gravity from storage bins into railway cars. Loading can also be done by steam shovel from storage piles. The following are the results of tests made on a sample of the stone:

Specific gravity	2·72
Weight, lb. per cu. ft.	169
Water absorption, lb. per cu. ft.	0·25
Percentage of wear	2·90
French coefficient of wear	13·8
Hardness	14·5
Toughness	4

While the low toughness would indicate a somewhat brittle stone, its wearing qualities are good. The even texture and massive structure of the rock contribute to give a product of uniform quality. The stone also breaks with a cleaner face and produces less dust than most stones of this class.

TABLE I

Results of Tests on Gravels

Sample No.	Location and owner	Character of material: Composition of pebbles: Durable	Intermediate	Soft	Type of stone, per cent	Shape of pebbles	Per cent of silt and clay	Per cent of wear	Amount available	Size of pit, cubic yards
	Huntingdon County									
1	Lot 20, Con. I, Dundee tp; Mrs. Watson.	20	50	30	Dolomite 55; limestone 20	Angular to subangular.	1·6	20·1	Gravel ridge about 4 times size of pit; max. depth at pit 13 feet.	9,000
5	Lot 61, Con. V, Godmanchester tp.; Township and C. N. R.	5	65	30	Dolomite 80....	Angular......	2·2	....	Coarser gravel about exhausted. Fine gravel below pit bottom is hard to get in large amount, because of bad drainage.	Over 200,000
6	Lot 55, Con. IV, Godmanchester tp; J. S. Leblanc.	5	75	20	Dolomite 80....	Angular......	4·6	....	Gravel terrace along N.W. margin of glacial-drift ridge. If whole terrace is gravel, amount is well over 10,000 cu. yds.	3,000
8	Lot 42, Con. IV, Godmanchester tp.; S. Barry.	0	60	40	Dolomite 90....	Angular......	2·7	29·1	Gravel found in long, narrow, glacial-drift ridge, averages 9 feet in depth at pit; amount unknown.	14,300
9	Lot 47, Con. II, Godmanchester tp.; U. Hurteau.	3	80	17	Dolomite 65; sandstone 20.	Angular......	4·1	....	Looks about exhausted. What is left is very sandy.	31,000
11	Lots 25, 26, Con. II, Godmanchester tp.; A. Mainville; J. Brunet.	15	80	5	Dolomite 50; sandstone 25.	Subangular....	....	....	Ridge of glacial drift, the crest of which holds looser material with a higher proportion of boulders and pebbles than down the slopes.	10,000
11a		15	75	10						
13	Lot 9, Con. II, Elgin tp.; F. Brown.	5	50	45	Dolomite 45; sandstone 35.	Angular to subangular.	3·2	....	Gravel ridge several times size of pit; max. depth at pit 15 feet.	15,500
13a	" "	15	70	15	....	....	1·3			

18	Lot 38, Con. III, Hinchinbrook tp.; R. Arthur.	7	78	15	Sandstone 85....	Angular to subangular.	2·9	....	Gravel terrace, average depth 7 feet. Amount at pit several times what already taken out.	4,100
18a		3	87	10			1·9			
21	Lot 27, Con. II, Franklin tp.; E. Roy.	5	80	15	Sandstone 90....	Angular.......	1·9	....	Gravel fills slight depression in underlying glacial drift; average depth 5 feet. Gravel said to cover at least 3 times the pit-area, that is at least 34,500 sq. yds.	15,100
21a	" "	7	73	20	....	....	1·2			
21b	" "	6	89	5	....	....	1·6			
24	Lot 81, Con. II, Havelock tp.; C. B. Edwards.	5	75	20	Sandstone 90....	Angular to rounded.	1·0	15·0	Gravel terrace running for miles; average depth at pit 9 feet.	3,700
24a	" "	0	80	20	....	....	2·4			
26	Lot 106, Con. III, Hemmingford tp.; R. Hayden.	0	65	35	Dolomite 85....	Angular.......	0·4	21·2	Amount probably very large; certainly as much as already taken out.	11,600
27	Lot 178, Con. V, Hemmingford tp.	10	63	27	Dolomite 90....	Angular.......	0·8	....	Gravel ridge at least 3 times size of pit; max. depth at pit 10 feet.	8,900
	Beauharnois County									
30	5 miles east of Valleyfield; J. Boyer.	3	81	16	Dolomite 90....	Angular.......	3·0	....	Long ridge of glacial drift; small pit shows material carrying high proportion of pebbles.	100
	Chateauguay County									
32	¾ mile west of Cairnside; D. Greig.	0	75	25	Sandstone 75....	Angular.......	0·6	....	Gravel forms small narrow band, max. depth 10 feet, along southeast margin of glacial drift ridge.	5,700
35	3 miles south of Ste. Philomène; T. Thibert.	25	65	10	Limestone 60; trap and syenite 20.	Angular to subangular.	2·3	9·4	Large, irregular gravel pockets or lenses in very large sand deposit, depth of sand at pit over 30 feet.	57,700
35a	....	....	....	....	....	....	2·0			

TABLE I—Continued

Results of Tests on Gravels—Continued

Sample No.	Location and owner	Character of material: Composition of pebbles: Durable	Inter-mediate	Soft	Type of stone, per cent	Shape of pebbles	Per cent of silt and clay	Per cent of wear	Amount available	Size of pit, cubic yards
	Chateauguay Co.—Con.									
37	2 miles southeast of Ste. Philomène; C. N. R.	25	65	10	Limestone 70....	Subangular....	1·2	9·2	About half of gravel owned by the railway company has already been taken out; max. depth at pit over 40 feet. Large amount available north-east of railway property.	Over 300,000
	Napierville County									
39	1¼ miles southwest of St. Michel; T. Bisson.	27	50	23	Trap and syenite 60; limestone 25.	Angular.......	2·0	....	Small flat gravel ridge; maximum depth at pit 7 feet. Amount unknown, but certainly twice as much as already taken out.	2,000
40	1 mile east of St. Rémi; O. Robert, F. Houle.	40	35	25	Trap 50; limestone 15.	Angular.......	3·2	....	Gravel forms slight elevation of large extent, but deposit includes much sand as judged by exposed part in large pit; maximum depth at pit 14 feet. Overburden 2 to 4 feet thick.	24,000
43	1¼ miles west of Napierville; E. Cyr, N. Fortin.	15	67	18	Limestone 35; trap 20; dolomite 10.	Angular.......	1·8	....	Gravel lies in southwest end of ridge; maximum depth at pit 10 feet. Amount unknown, but certainly as large as already taken out.	15,400
	St. Johns County									
46	2 miles west of Odelltown; Parish of St. Bernard.	5	80	15	Dolomite 55; limestone 35.	Subangular to angular.	1·6	13·2	Large gravel deposit; maximum depth at pit over 20 feet.	15,200

50	2 miles west of St. Valentin; C. Deneault.	10	23	67	Limestone 20; soft pebbles intensely weathered.	Angular......	1·3	....	Gravel ridge about 5 times size of pit; averages 6 feet in depth.	1,800
51	2¾ miles southwest of St. Blaise; B. Breault.	45	47	8	Limestone 40; trap 30; gneiss and granite 20.	Angular to subangular.	1·2	....	Same deposit as No. 53...	19,600
53	2 miles southwest of St. Blaise; A. Gagnon.	33	50	17	Limestone 35; syenite 40.	Angular to subangular.	1·8	....	Narrow, flat ridge several miles long, holds more sand than gravel; averages 100 feet in width and 6 feet in depth.	16,700
55	3½ miles southwest of St. Johns; A. Tremblay, A. Roulier.	25	55	20	Limestone 30; trap 30.	Angular......	0·9	14·1	Flat ridge, averages 7 feet in depth. Gravel more than half exhausted. Overburden up to 3 feet in thickness.	19,900
	Chambly County									
56	½ mile north of St. Bruno; E. Goyer.	40	25	35	Trap 20; gneiss 20; soft pebbles intensely weathered.	Angular......	2·3	....	Gravelly sand deposit in lower south slope of St. Bruno Mountain; averages 8 feet in depth. Much more sand than gravel, and covered with thick overburden of sand.	6,400
57	1¼ miles west of St. Basile; F. H. Clergue.	90	3	7	Trap 95........	Angular......	1·2	4·9	Gravel terrace in southeast slope of St. Bruno Mountain. Large pit 10 to 20 feet deep, reaches bottom of deposit in places only. Amount very large.	43,000
	Iberville County									
60	2 miles northeast of St. Alexandre; J. Breault.	13	30	57	Sandstone and shale 40.	Angular......	1·3	....	Gravel ridge several times size of pit; average depth 7½ feet; underlain by fine sand.	13,500
63	1 mile northeast of St. Grégoire; E. Tetreau.	25	50	25	Trap 40; sandstone and shale 40.	Angular to subangular.	0·7	....	Gravel terrace at the foot of Mount Johnson; maximum depth 22 feet. Very large deposit but includes more sand than gravel and is covered with 2 to 4 feet of sand as overburden.	27,500

TABLE I—Continued

Results of Tests on Gravels—Continued

Sample No.	Location and owner	Character of material						Per cent of wear	Amount available	Size of pit, cubic yards
		Composition of pebbles				Shape of pebbles	Per cent of silt and clay			
		Durable	Intermediate	Soft	Type of stone, per cent					
	Iberville Co.—Con.									
64	1¼ miles northeast of St. Grégoire; U. Benoit.	30	65	5	Sandstone and shale 50; gneiss 35.	Angular.......	0·7	....	Gravel bluff at the foot of Mount Johnson; deep deposit of very large size, but includes much sand and is in places covered with thick overburden of sand.	53,700
65	2¼ miles northwest of St. Grégoire; E. Metras, Dept. of Highways.	55	30	15	Trap 45; gneiss and granite 30; limestone 10; sandstone and shale 15.	Angular to subangular.	0·4	8·8	Very slight but wide gravel-elevation several times size of pit; average depth 7½ feet.	100,000
65a		25	45	30			1·0			
	Missisquoi County									
70	Lot 47, Con. I, Farnham West; C. Laurin.	10	30	60	Pebbles are mostly shale or slate and trap.	Subangular....	1·4	32·2	Small deposit, thickly covered with sand in places. At least 7,000 cubic yards available without too much stripping.	16,600
70a	" "	10	30	60	....	....	1·3			
71	2 miles southeast of Frelighsburg; B. Wilson.	20	53	27	Slaty limestone and calcareous slate 60.	Subangular....	1·8	....	Several large, deep deposits forming steep knolls.	6,400
72	Lot 3, Con. X, Dunham tp.; G. Barnes.	15	38	47	Slate 50; sandstone 35.	Subangular....	2·5	....	Gravel forms low, narrow ridge, several hundred yards in length; average depth 6 feet. Over 10,000 cubic yards available.	1,700
74	Lot 28, Con. V, Dunham tp.; Municipality of Cowansville.	27	63	10	Slate 60; sandstone 30.	Subangular and some flat.	0·6	....	See No. 75.............	13,300

75	Lot 28, Con. VI, Dunham tp.; Dept. of Highways.	35	55	10	Slate 50; sandstone 30.	Subangular and some flat.	0·3	8·8	Gravel deposit forms steep bluff along Yamaska River, for a distance of over ¾ miles, including No. 74 and other smaller pits. Over 100,000 cubic yards available.	24,000
75a	" "	45	45	10	....	....	0·5			
	Rouville County									
77	2½ miles east of Abbotsford; C. Ball.	60	35	5	Limestone 30; sandstone 25; trap 20.	Subangular....	0·5	5·7	Deposit forms large ridge over one mile long, with maximum depth of over 25 feet. Overburden 4 feet of fine sand.	8,300
79	¾ mile west of Mont St. Hilaire; A. Guertin.	33	33	34	Trap 45; gneiss and granite 30.	Subangular....	1·7	....	Gravel deposit forms part of large terrace at the foot of Mount St. Hilaire, has an average depth of 7½ feet and is said to have an area of about 25 acres.	7,600
80	1 mile southeast of St. Hilaire; R. Desourdy.	90	5	5	Trap 80; gneiss and granite 10.	Subangular....	1·2	4·4	Deposit very shallow and of small extent.	5,500
	Bagot County									
82	2 miles southeast of St. Dominique; F. X. Breault.	7	48	45	Shale 40; limestone 25.	Angular.......	0·6	26·7	Large, flat-lying gravel deposit, with an average depth of 9 feet. Large amount available, but better grade gravel now almost exhausted.	142,000
83	2 miles southeast of St. Dominique; A. Lebeau.	20	40	40	Limestone 25; gneiss and granite 25; shale 20.	Angular.......	0·8	23·9	Probably very large amount.	36,400
84	2½ miles east of St. Dominique; M. Deslandes.	15	45	40	Shaly limestone and shale 70; gneiss 20.	Angular to subangular.	1·3	....	Deposit forms large ridge and has a maximum depth of more than 25 feet. Includes both Nos. 84 and 85, and amount available is more than already taken out in both pits.	10,400
84a	" "	12	63	25	....	....	0·5			

50633—8

TABLE I—Continued

Results of Tests on Gravels—Continued

Sample No.	Location and owner	Character of material						Per cent of wear	Amount available	Size of pit, cubic yards
		Composition of pebbles				Shape of pebbles	Per cent of silt and clay			
		Durable	Inter-mediate	Soft	Type of stone, per cent					
	Bagot Conuty—Con.									
85	2½ miles east of St. Dominique; A. Dubreuil.	15	55	30	Shaly limestone and shale 60; granite and gneiss 25.	Angular to subangular.	1·1	18·3	Same as No. 84..........	49,400
86	1½ miles south of St. Liboire; J. Rodier.	10	40	50	Limestone and slate or shale 80.	Angular.......	1·1	....	Large ridge-like deposit, averaging 15 feet in depth. There remains as much available as already taken out.	50,600
87	1½ miles southeast of St. Liboire; A. Desmarais.	5	50	45	Limestone and slate or shale 80.	Angular and flat.	1·8	24·3	Gravel lies in southwest slope of flat ridge, and said to have been traced to the southeast for a distance of at least 1,000 feet, which would place the amount available at 25,000 cubic yards.	7,500
90	1½ miles northwest of St. Lihoire; H. Montmarquette.	5	35	60	Limestone and slate or shale 80.	Angular......	1·1	30·7	Deposit has an average depth of 7½ feet. Amount of gravel unknown; at least as much as already taken out. Overburden 2½ to 4 feet of fine clayey sand.	10,100
95	Lot 33, Con. VI, Acton tp.; H. Guérin, J. St. Amand.	40	40	20	Sandstone 55; slate or shale 30.	Angular and flat.	1·3	14·0	Gravel forms flat ridge and averages 6 to 7 feet in depth. Over 30,000 cubic yards available.	6,100
97	Lot 29, Con. VI, Acton tp., H. Champagne.	20	70	10	Slate 40; trap 15; sandstone 10.	Angular to subangular.	0·8	....	Large, deep deposit lying in the upper, east slope of a rocky ridge. Gravel overlain with 10 to 15 feet of fine sand, the latter having been blown away in many places.	Over 1,000

59633—8½

101	Lot 14, Con. III, Acton tp.; Mrs. Bisaillon.	5	75	20	Slate or shale 65; sandstone 20.	Angular and flat.	1·2	....	Deposit almost exhausted.	15,100
	Brome County									
107	Lot 4, Con. II, Brome tp.; W. MacNeil.	45	45	10	Slate and schist 20; many other types.	Angular to subangular.	1·2	....	Deposit forms three large steep - sloped knolls, which hold more sand than gravel. Knolls cover 4 acres and average 40 feet in height.	1,600
108	Lot 7, Con. II, Brome tp.; Dept. of Highways.	40	45	15	Slate and schist 40; sandstone 25.	Angular to subangular.	0·5	9·4	Several steep knolls, gravelly on surface, aggregate well over 100,000 cubic yards in size.	9,300
109	Lot 10, Con. VI, Brome tp.; J. C. Soles.	35	40	25	Slate and schist 30; many other types.	Angular to subangular.	2·4	17·2	Gravel lies in central part of small ridge. Amount at least ten times size of pit.	2,800
112	Lot 16, Con. V, Potton tp.; Dept. of Highways.	40	40	20	Schist and slate 40; quartzose 25.	Subangular....	4·0	....	Deposit forms steep knoll, 30,000 cubic yards in size. Gravel covered with 4 to 5 feet of sand as overburden.	1,400
113	Lot 2, Con. VI, Bolton tp.; D. Coates.	25	55	20	Schist and slate 45; quartzose 35.	Angular to subangular.	1·2	....	Gravel forms pocket in large sand area; average depth 7 feet. Other similar pockets seen elsewhere in the sand area.	900
115 115a	Lot 11, Con. I, Bolton tp.; M. Hunt.	47 50	38 30	15 20	Schist 35; trap and metamorphic 30.	Angular to subangular.	0·7 0·6	8·7	Gravel forms ridge or knoll at least ten times size of pit.	4,900
	Shefford County									
117	Lots 3, 4, Con. I, Shefford tp.; A. Sirard; M. McMahon.	15	65	20	Trap 40; slate or shale 30.	Angular......	5·3	....	Shallow deposit, 2 to 8 feet in depth, on top of loose rock, covers several acres.	Over 10,000
120	Lot 17, Con. II, Milton tp.; G. Messier.	25	50	25	Slate or shale 55; sandstone 35.	Flat and subangular.	1·4	....	Gravel overlies bedrock, and depth varies owing to the irregular surface of the rock, but deposit generally very shallow Pit averages 4 feet in depth. Deposit flat-lying and extent unknown, but apparently large.	7,400

TABLE I—Concluded

Results of Tests on Gravels—Concluded

Sample No.	Location and owner	Character of material: Composition of pebbles: Durable	Intermediate	Soft	Type of stone, per cent	Shape of pebbles	Per cent of silt and clay	Per cent of wear	Amount available	Size of pit, cubic yards
	Shefford Co.—Con.									
121	Lot 2, Con. I, Milton tp.; S. Paul.	20	55	25	Slate or shale 45; metamorphic 30.	Angular and flat.	0·8	18·0	Pit dug to maximum depth of 12 feet does not reach bottom of deposit, which is at least three times pit size.	14,300
125	Lot 16, Con. X, Roxton tp.; N. Raymond.	20	65	15	Slate or shale 55; sandstone 28.	Subangular to angular.	0·3	12·6	Deposit lies on top of a steep bluff facing river. It averages 7 feet in depth and is at least 3 times size of pit.	8,400
129	Lot 23, Con. VII, Shefford tp.; Mrs. C. McLaughlin.	35	40	25	Sandstone, 45; slate or shale 35.	Angular to subangular.	0·9	14·9	Deposit forms steep ridge along river bank. Part of ridge is sand. Over 10,000 cubic yards of gravel available.	4,600
132	Lot 27, Con. VIII, Shefford tp.; Dept. of Highways.	15	50	35	Schist 30; slate or shale 20; sandstone 20.	Angular to subangular.	1·7	....	Deep deposit forming steep ridge, about ten times size of pit. Upper 4 to 8 feet of pit bank is bouldery and weathered. Maximum height of pit bank is 25 feet.	4,800
133	Lot 16, Con. IX, Stukely tp.; Z. Gervais.	50	40	10	Metamorphic 50; slate 30.	Subangular to angular.	0·4	7·8	Gravel forms large ridge and its depth is not known; is said by patrolman to underlie large area outside of ridge. Ridge alone measures over 200,000 cubic yards.	27,000
137	Lot 15, Con. I, Ely tp.; E. Ferland.	33	42	25	Many rock types.	Angular......	1·1	....	Small deposit with an average depth of 6 feet. Amount available about twice as much as already taken out.	1,800

	Drummond County									
138	Lot 11, Con. X, Durham tp.; Bonner Sand and Ballast Co.	35	50	15	Metamorphic 45; slate 40.	Angular to subangular.	1·0	10·0	Very large deposit. Pit has a maximum depth of 80 feet and does not reach bottom.	Over 1,000,000
139	Lot 10, Con. IX, Durham tp.; E. Reed;	23	62	15	Slate 60; sandstone 20.	Angular to subangular.	0·5	....	Deposit of very large size, but includes more coarse sand than gravel. Fresh material lies under 3 to 4 feet of weathered, worthless sand.	20,000
139a	J. E. Mitchell.	23	67	10	....	....	0·6			
140	Lots 14, 15, Con. IX, Durham tp.; Dominion Sand and Stone Co.	20	65	15	Metamorphic 40; slate 40.	Angular to subangular.	0·9	13·4	Very large deposit mostly of coarse sand, but gravel or sand of any coarseness desired is available. Pit bank has a maximum depth of 100 feet.	Over 1,000,000
140a	" "	....	....	....	....	....	0·9			
141	Lot 24, Con. I, Durham tp.; T. Labonté.	60	30	10	Many rock types.	Subangular to angular.	0·0	....	Very large deposit but includes more coarse sand than gravel. Fresh material covered with several feet of worthless sand and silt.	19,000
142	Lot 15, Con. IX, Wickham tp.; A. Lepage.	33	44	23	Sandstone 50; slate and schist 35.	Angular......	1·1	....	Flat-lying and shallow deposit, said by patrolman to cover 15 acres. Pit depth averages 7½ feet, with bouldery gravel or glacial drift in the bottom.	11,600
143	Lot 1, Con. VIII, Wendover tp.; A. Lafond.	10	60	30	Slate and shale 80.	Flat and angular.	0·6	....	Gravel forms several small, shallow, ridge-like deposits, 5 feet in average depth. A somewhat deeper and much larger deposit, formerly worked for railway-ballast, is now almost exhausted.	2,300
144	Lot 1, Con. XIII, Wendover tp.; Dept. of Highways.	40	25	35	Many rock types.	Angular......	1·5	....	Deposit forms flat-topped ridge and averages 4½ feet in depth. Ridge of large extent, but includes much bouldery, poorly graded material.	31,000

TABLE II
Results of Tests on Gravels

Sample No.	Proportion of pebble to sand		Granulometric Analysis													Per cent passing 200 mesh	Remarks
			Pebbles							Sand							
			Per cent retained on screens							Per cent retained on sieves							
	Per cent pebble	Per cent sand	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
1	73	27	4	11	14	19	10	19	23	38	24	15	8	5	4	6	Very coarse and bouldery; all boulders of small size. With coarser material screened out, makes a well graded, good surfacing gravel of moderate durability. Sampled at depth of 4 to 8 feet, in average size of gravel (boulders 10 per cent.)
5	45	55	0	4	0	9	7	14	66	58	26	6	2	2	2	4	High proportion of soft pebbles: sampled near pit bottom. It is the best road gravel available locally and makes a very smooth surface.
6	34	66	0	0	5	6	9	20	60	47	26	7	6	4	3	7	Gives good results. Rather sandy, but sand very coarse. Sampled at depth of 9 to 12 feet, in average size material.
8	61	39	0	9	8	24	16	18	25	42	30	13	4	2	2	7	Very coarse and bouldery. Gravel weathered, with high proportion of soft. With coarser material screened out, is well graded, but makes dusty road surface. Sample represents average coarseness (boulders 10 per cent).
9	18	82	0	39	12	13	7	10	19	6	32	46	7	2	2	5	Very little used now: too sandy. Coarser grade looks about exhausted. Sample finer but more regularly graded than average.
11	(Sample of crushed material)																Very coarse and bouldery glacial drift (boulders 33 per cent). Crushed for road purposes because no gravel available. Samples of crushed material show lower proportion of soft than pit bank.
11a	(Sample of crushed material)																
13	55	45	0	0	15	14	11	19	41	39	11	3	17	17	6	7	Fine gravel, very sandy in places. Good, though rather dusty. Sample 13 from depth of 3 to 4 feet; 13a, 8 to 9 feet. Very sandy phase not included in the samples.
13a	36	64	0	0	0	8	6	16	70	55	12	1	12	15	3	2	
18	42	58	0	0	0	3	4	6	87	60	22	5	3	3	2	5	Fine, well graded gravel, with about 50 per cent coarse sand, and very little weathered material. Makes hard and smooth road. Sample 18, average as to coarseness; 18a, coarser than average.
18a	63	37	0	0	2	6	8	20	64	61	14	7	6	4	3	5	

21 21a 21b	37 40 68	63 60 32	0 0 0	8 2 0	9 2 0	22 16 5	11 9 16	18 23 27	32 48 52	22 29 61	47 20 10	22 42 9	2 4 6	2 2 5	2 1 4	3 2 5	Well graded and comparatively free from weathered material, but rather sandy. Much used on roads with good results. Samples 21 and 21a are from average size gravel; 21b is from better graded, less sandy gravel than average, found only in north edge of deposit.
24 24a	93 70	7 30	3 0	7 5	15 8	24 19	12 10	19 17	20 41	23 39	16 18	13 19	14 8	12 4	8 4	14 8	Generally coarse and bouldery, with low proportion of sand; streaks of finer gravel. The finer phase makes a hard, smooth surface. Sample 24 coarser and less sandy, 24a finer and more sandy than average.
26	58	42	0	12	7	25	13	19	24	19	9	10	53	7	1	1	Low proportion of small pebbles and coarse sand. Does not compact readily on road on account of too much fine sand. Sample, from depth of 3 to 5 feet, represents average as to coarseness and freshness.
27	60	40	12	18	11	22	9	12	16	26	24	25	16	5	2	2	Fairly well graded, with rather high proportion of weathered pebbles: sample from depth of 5 to 7 feet. Makes very smooth, but dusty road surface.
30	73	27	0	18	22	20	12	14	14	19	13	16	26	10	5	11	Carries enough pebbles to make a fair road surface. Very little used.
32	37	63	0	7	15	16	13	19	30	13	9	15	42	17	3	1	Carries much fine sand and rather high proportion of weathered pebbles: Sample from depth of 5 feet. Makes hard, smooth, but dusty road surface.
35 35a	71 0	29 100	5 0	7 0	27 0	17 0	10 0	13 0	21 0	48 0	23 0	9 22	5 63	4 11	3 2	8 2	Sand much used on roads because it compacts very readily to a hard, smooth surface; wears fast. Sample 35 from streak of coarse gravel, depth 17 feet; 35a from sand, depth 30 feet.
37	42	58	31	5	9	16	8	12	19	15	21	44	14	3	1	2	Pit bank 2,300 feet in length. Coarseness of gravel varies in a regular way; very coarse and somewhat bouldery underneath the top of the hill, very fine and sandy in the lower slope, at pit entrance. Sample taken 700 feet from hill top, at depth of 11 feet. A large proportion of the bank shows good road-gravel.
39	49	51	0	0	3	11	20	23	43	36	27	19	7	5	2	4	Well graded, but too fine and sandy; averages 75 per cent sand. Sample is from coarsest phase, depth 1½ to 7 feet. Gives good results on clay roads.
40	37	63	0	4	0	27	15	20	34	32	25	21	10	4	3	5	Well graded but very fine and sandy; averages 75 per cent sand. Sample coarser than average, depth 4 to 7 feet. Good on clay roads, although dusty.
43	41	59	0	0	3	17	16	23	41	21	16	17	32	9	2	3	Gravel carries rather fine sand. Makes a smooth but dusty road surface.

TABLE II—Continued

Results of Tests on Gravels—Continued

Sample No.	Proportion of pebble to sand		Granulometric Analysis													Per cent passing 200 mesh	Remarks
			Pebbles							Sand							
			Per cent retained on screens							Per cent retained on sieves							
	Per cent pebble	Per cent sand	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
46	88	12	4	5	28	25	12	12	14	50	14	8	5	5	5	13	Very coarse gravel, with less than 25 per cent sand: sample, from depth of 5 to 8 feet, less sandy than average. Crushed gravel makes very smooth, but very dusty road.
50	35	65	0	0	17	16	13	19	35	18	14	22	37	5	2	2	Gravel weathered and very soft. Compacts readily on road, but wears fast.
51	41	59	0	0	7	14	13	26	40	23	16	18	28	12	1	2	Fresh, fairly well graded gravel, but a little fine. Makes hard, smooth and durable road surface.
53	40	60	0	3	7	18	14	19	39	26	22	20	18	9	2	3	Same as No. 51, except that grading is more regular.
55	69	31	0	6	16	21	11	18	28	39	23	16	11	6	2	3	Coarse, sandy, poorly graded, weathered, soft and dusty. Wears fast on road. Part of deposit, under 3 feet of overburden, holds fresher, finer, and less sandy gravel than average; sample is from fresher part, which is used only for concrete works.
56	23	77	0	0	0	16	12	18	54	20	18	21	24	12	2	3	Soft and very sandy. Sample from coarser and fresher phase, near bottom of deposit.
57	70	30	11	8	15	22	12	16	16	35	26	19	10	4	2	4	Very coarse and bouldery, low in sand; sample from finer than average, depth 4 to 9 feet. Compacts readily to a very hard, though somewhat rough surface. Very good for foundation course.
60	35	65	3	0	7	17	14	24	35	13	8	15	45	16	1	2	Soft with much fine sand: sample coarser and less sandy than average, depth 2½ to 5 feet. Wears fast on road and is dusty, but is the best available for miles.
63	29	71	0	0	5	16	12	25	42	18	16	20	36	8	1	1	Soft and very sandy: sample less sandy than average, depth 15 to 20 feet. Does not compact readily.
64	33	67	22	7	8	8	11	16	28	16	12	19	36	13	3	1	Varies much in coarseness. Sample, taken from deep in the bank, is fresher than average. Gravel of suitable coarseness for roads found only in places.

65 65a	56 48	44 52	0 0	7 4	6 6	29 8	15 7	17 16	26 59	27 33	14 14	13 9	27 30	15 11	3 1	1 2	Generally coarse and sandy; one large section of pit bank shows fine gravel carrying up to 75 per cent sand and is probably near the edge of the deposit. Good road gravel, but somewhat too sandy.
70 70a	52 33	48 67	3 0	6 0	8 4	18 8	15 13	19 20	31 55	28 33	28 33	24 19	11 8	4 4	2 1	3 2	Well graded, but much weathered and dirty. On roads, has a strong binding power, but wears fast.
71	65	35	0	3	9	20	12	21	35	52	27	7	4	3	2	5	Generally fine, with about 50 per cent very coarse sand; sample taken at depth of 15 feet, in coarsest phase. Rather soft and sandy, but makes firm, smooth road.
72	50	50	0	5	14	17	9	16	39	42	28	16	5	2	2	5	Well graded, but partly weathered and soft; sample represents average *re* coarseness and freshness. Makes a smooth, firm road surface.
74	37	63	0	5	10	15	11	22	37	19	21	35	20	3	1	1	Carries at least 75 per cent sand; sample represents coarsest and least sandy phase. Too sandy.
75 75a	66 50	34 50	0 0	11 18	15 5	27 14	11 10	16 17	20 36	33 46	34 36	25 12	5 4	1 1	1 0	1 1	Fine gravel, carrying about 50 per cent very coarse sand; sample 75 is from coarsest phase; 75a from average as to coarseness. Very good road gravel; partly worn road surface turns somewhat muddy when wet.
77	76	24	0	8	16	29	15	16	16	28	21	17	19	11	2	2	Very hard and fresh gravel, varying from coarse to fine; sample coarser and less sandy than average. Coarser gravel gives very good results on roads.
79	15	85	0	0	0	3	19	22	56	20	27	26	19	5	1	2	Although mostly sand, material compacts readily to a smooth, firm surface, under light traffic.
80	60	40	0	6	17	22	14	17	24	27	24	28	14	2	2	3	Well graded, hard and coarse. Does not compact to a smooth surface, but wears well.
82	44	56	0	9	20	20	11	17	23	14	11	19	45	9	1	1	Soft gravel carrying much fine sand. Makes smooth but fast wearing, dusty road surface.
83	59	41	3	7	9	13	13	23	32	18	7	12	39	16	6	2	About the same as No. 82. Sample 83 is from deeper and fresher material than No. 82.
84 84a	33 50	67 50	0 4	0 9	6 11	12 21	12 13	23 15	47 27	17 18	14 12	15 11	39 40	12 16	1 2	2 1	About the same as No. 82. Sample 84 is from partly weathered, fine gravel, depth 3½ to 8 feet; 84a from fresh gravel of average coarseness, depth 17 to 22 feet.
85	82	18	4	22	21	22	9	10	12	27	21	17	13	11	5	6	About the same as No. 82. Sample 85 is from a streak of very coarse, fresh gravel, low in sand.
86	45	55	0	6	18	18	10	18	30	17	14	15	35	15	2	2	Carries right amount of pebbles and sand, but the latter is too fine. Wears evenly but fast and is dusty.
87	75	25	13	14	13	22	10	14	14	25	19	15	11	17	6	7	Coarse to fine, well graded, soft gravel. Makes smooth but fast wearing, dusty road surface. Sample coarser and less sandy than pit average

TABLE II—Continued

Results of Tests on Gravels—Continued

Sample No.	Proportion of pebble to sand		Granulometric Analysis													Per cent passing 200 mesh	Remarks
			Pebbles							Sand							
			Per cent retained on screens							Per cent retained on sieves							
	Per cent pebble	Per cent sand	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
90	43	57	0	2	15	22	14	19	28	18	13	19	34	11	3	2	About the same as No. 87, but more uniform in coarseness, more sandy and softer.
95	58	42	6	5	8	12	12	21	36	37	24	20	12	3	1	3	Well graded, medium fine, fairly hard gravel. Sample coarser and less sandy than pit average. Consolidates very firmly on the road and wears well.
97	59	41	0	4	2	16	11	24	43	42	31	19	3	2	1	2	Clean, fresh, well graded gravel, very uniform in coarseness. Very good results are obtained in road surfacing. Makes also a very good concrete aggregate.
101	39	61	0	0	12	12	12	24	40	22	30	26	14	5	1	2	Well graded, fine gravel, but rather too sandy. Sample less sandy than pit average. Gravel of proper size for roads is now almost completely exhausted.
107	61	39	0	12	10	25	12	19	22	30	26	26	11	3	1	3	Pit face shows much more sand than gravel. Sample from layer of well graded gravel represents coarsest phase. Much better as cement than as road gravel.
108	76	24	5	13	11	17	13	16	25	40	30	16	6	4	2	2	Only part of large pit face exposed. Gravel varies in coarseness and turns very sandy in depth, but is generally well graded. Sample from coarser and less sandy layer than average. Compacts readily on the road and makes a smooth, durable surface.
109	70	30	9	7	15	17	10	17	25	39	22	13	8	6	4	8	About the same as No. 108, but more uniform in coarseness, and not quite so fresh and durable. Sample from coarser material than pit average.
112	67	33	0	19	14	18	12	16	21	32	25	15	7	4	5	12	In upper half of 20-foot pit bank, coarseness varies irregularly; lower half well graded, with 50 per cent sand, mostly coarse. Sample from lower half is less sandy and coarser than average for that part. Gravel is only moderately durable, but is the best available locally.

113	38	62	0	0	7	13	12	20	48	29	26	24	14	4	1	2	Uniform in coarseness and well graded, but too sandy. Has been in use only a short time and compacts well under traffic.
115	63	37	0	12	8	23	10	19	28	35	27	19	13	3	1	2	Fine, well graded, rather sandy gravel. Sample No. 115a is from average size gravel; No. 115 from coarser gravel than average. Very good road-gravel.
115a	40	60	0	0	6	15	8	25	46	25	29	33	10	2	0	1	
117	72	28	2	5	10	19	18	27	19	11	10	13	17	19	11	19	Poorly graded: not enough medium size material; proportion of sand varies much. Sample less sandy than average. Does not compact firmly on roads.
120	62	38	0	2	10	16	13	24	35	40	27	16	9	3	1	4	Generally well graded, but coarseness and proportion of sand vary. Sample, taken at depth of 1½ to 3 feet, is from least sandy phase, and of average coarseness. Compacts well and although only moderately durable is the best gravel found locally.
121	72	28	9	16	12	18	12	17	16	30	19	18	17	10	3	3	Coarseness varies in a regular way and gravel is well graded, though high in sand in places. Sample, taken at depth of 6 to 10 feet, represents least sandy phase. As road gravel, it is about the same as No. 120.
125	69	31	4	3	14	22	11	17	29	36	27	23	10	2	1	1	Good, well graded road gravel, very uniform in coarseness. Makes a smooth, durable road. Unsuitable as concrete aggregate.
129	55	45	13	8	16	15	9	12	27	29	29	27	10	2	1	2	Varies much in coarseness. Sample represents the better graded phase.
132	57	43	0	0	8	21	10	27	34	40	29	17	6	3	1	4	Very well graded and uniform, outside of upper 4 to 8 feet where gravel is very bouldery and weathered. Compacts well but is not very durable.
133	56	44	23	19	14	11	7	9	17	23	36	32	5	2	1	1	Varies much in coarseness but is on the whole well graded. Very good and durable results are obtained in road surfacing.
137	44	56	0	5	3	12	10	23	47	32	25	25	13	2	1	2	Rather sandy, but well graded and uniform in coarseness, with 55 to 65 per cent sand, mostly coarse. Consolidates firmly and wears well and evenly.
138	68	32	5	13	14	20	13	15	20	31	16	9	13	21	7	3	Large pit face shows mostly coarse gravel, but also fine gravel and sand. Sample, taken from layer of coarse gravel for abrasion test, does not represent average coarseness and grading. Product is sold for railway ballast, roads and concrete.
139	55	45	0	3	8	19	14	22	34	32	21	15	16	12	3	1	Deposit holds mostly coarse sand, with an occasional layer of gravel or gravelly sand. Both samples are from gravelly layers. The material is fresh and of good quality as concrete aggregate, but most of it is too fine for roads.
139a	36	64	0	0	5	6	8	26	55	26	22	22	19	8	2	1	

TABLE II—Concluded

Results of Tests on Gravels—Concluded

Sample No.	Proportion of pebble to sand		Granulometric Analysis: Pebbles — Per cent retained on screens							Granulometric Analysis: Sand — Per cent retained on sieves						Per cent passing 200 mesh	Remarks
	Per cent pebble	Per cent sand	2½″	2″	1½″	1″	¾″	½″	¼″	8	14	28	48	100	200		
140	78	22	6	7	14	19	13	17	24	47	19	12	9	6	3	4	Large pit face shows mostly coarse sand, but also gravel of any coarseness. Sample 140 is from layer of coarse gravel for abrasion test; 140a from a layer of coarse sand. Product is sold for concrete, roads, and railway ballast.
140a	6	94	0	0	0	0	12	16	72	14	30	30	19	5	1	1	
141	38	62	0	0	2	14	7	25	52	28	19	26	22	4	1	0	Much too sandy (sand averages 75 per cent) but otherwise uniformly well graded. Very good cement gravel. Good results are obtained in road maintenance work with coarser phase material, as represented by sample.
142	43	57	0	0	6	12	12	27	43	25	25	23	20	4	1	2	Well graded, uniform in coarseness, rather sandy with sand generally coarse. Good and durable road gravel.
143	72	28	0	5	3	22	20	23	27	54	23	12	4	3	2	2	Uniformly well graded. Compacts firmly and makes a very smooth road surface, but is durable only under light traffic, and old roads are somewhat muddy when wet.
144	70	30	0	5	10	27	20	17	21	25	14	22	25	6	3	5	Well graded, fine gravel, but rather sandy. Sample represents coarser and less sandy phase. Compacts well but is durable only under light traffic.

TABLE III

Mortar Tests*

Sample No.	Fineness modulus	Sand mortar: 1 cement: 3 sand					Remarks
		Per cent of water used	Tensile strength, per cent of standard		Compressive strength, per cent of standard		
			7 days	28 days	7 days	28 days	
1	3·52	13·9	125	111	117	123	Slightly weathered.
5	4·18	12·1	134	136	145	141	
6	3·76	13·0	145	122	165	145	
8	3·79	12·8	106	111	144	141	Slightly weathered.
9	3·12	13·8	110	106	111	109	
13	2·99	15·1	85	82	97	96	Sand from sample 13, taken near surface, is slightly dusty and rather fine; 13a, taken deeper, is coarse and clean.
13a	3·65	12·7	139	124	156	158	
18	4·12	12·5	125	114	157	139	
21a	3·61	13·8	85	73	110	110	Sample from near surface. Deposit shallow.
26	2·74	13·9	84	106	85	107	Sand too fine.
27	3·38	11·9	177	137	190	161	
32	2·47	13·7	95	100	90	105	Sand too fine.
35	3·73	14·9	135	111	139	125	Sample 35 dusty; 35a clean but fine; both samples taken deep in the bank.
35a	2·03	16·0	81	71	61	65	
37	3·22	13·3	116	113	117	127	
39	3·64	14·5	138	109	132	120	
40	3·47	16·5	99	83	70	86	Sample of partly weathered material, depth 4 to 7 feet.
43	2·93	13·8	106	100	106	114	Rather fine and slightly weathered.
51	3·01	13·9	89	111	96	110	Slightly weathered.
53	3·23	15·4	113	103	100	110	Slightly weathered.
55	3·63	12·9	122	117	108	120	Slightly dusty and weathered.
56	2·95	16·1	87	96	93	93	Rather fine and grains slightly dust coated.
60	2·48	13·8	68	87	81	95	Clean, fresh sand, but too fine.
63	2·94	13·9	111	111	132	134	
64	2·70	13·0	98	113	93	108	Clean, sharp sand, but too fine.
65	2·99	14·6	90	99	85	101	Both samples hold small amount of mica, which accounts for low results.
65a	3·19	13·9	75	88	101	113	
71	4·00	13·9	153	117	135	120	Sand clean and coarse, but rather soft.

* Only the material passing a ¼-inch screen (sand or fine aggregate) is used for this test. The fineness modulus is an indication of the fineness of the sand; the finer the sand the lower will be its modulus. The standard test referred to is made on a mortar composed of 1 part of cement and 3 parts of standard Ottawa sand. Mortars giving results of at least 100 per cent of the value of the standard test are considered suitable for all conditions and are classified as high grade; those testing over 70 per cent and less than 100 per cent of the standard are suitable only for certain classes of work; those testing less than 70 per cent of the standard should be rejected.

As already stated, nearly all the samples were collected primarily for testing as road material, and are not therefore truly representative of that part of the deposit best suited for mortar or concrete works.

TABLE III—*Concluded*

Mortar Tests*—Concluded

Sample No.	Fineness modulus	Sand mortar: 1 cement: 3 sand					Remarks
		Per cent of water used	Tensile strength, per cent of standard		Compressive strength, per cent of standard		
			7 days	28 days	7 days	28 days	
72	3·82	15·1	91	94	78	81	Weathered, dusty, soft sand.
74	3·27	12·5	147	130	123	123	
75	3·87	10·7	186	165	177	174	
75a	4·19	10·9	183	165	161	173	
77	3·24	12·1	131	135	140	150	
79	3·29	13·5	115	96	129	110	Grains coated with fine dust.
80	3·45	13·7	53	67	46	78	Slightly rusty and dusty. Sample from near surface. Deposit shallow.
82	2·70	13·9	101	110	95	109	Clean, but too fine.
83	2·48	14·6	90	99	85	101	Too fine sand.
84a	2·67	13·8	93	106	100	107	Clean, but too fine.
85	3·07	15·4	114	123	101	104	
86	2·71	13·9	121	110	117	119	
87	2·85	19·1	82	83	71	77	Medium fine and dusty.
90	2·78	14·3	120	115	100	107	
95	3·67	13·9	114	104	108	108	
97	3·99	11·7	170	143	183	164	
101	3·41	13·2	113	95	114	119	Grains slightly dust coated. Sample from near surface.
107	3·57	12·5	151	139	176	146	
108	3·84	11·6	202	165	177	159	
109	3·44	13·9	143	126	135	150	
112	3·23	13·7	125	136	152	147	
113	3·53	13·1	104	111	122	126	
115	3·69	11·4	159	133	157	150	
115a	3·62	12·1	132	127	145	146	
120	3·77	13·9	57	69	71	87	Sand holds dust and organic matter. Sample from near surface.
121	3·24	13·7	118	140	115	128	
125	3·79	13·1	20	58	10	42	Grains slightly coated with clay mixed with organic matter. Sample from near surface.
129	3·64	12·1	153	136	141	136	
132	3·82	13·4	138	127	118	130	
133	3·67	11·2	159	143	149	153	
137	3·63	13·7	83	87	81	88	Rusty and dusty. Sample from near surface. Deposit shallow.
139	3·33	11·6	162	146	153	140	
139a	3·30	11·6	147	145	157	165	
140	3·71	13·2	143	132	143	158	
140a	3·23	11·3	155	150	122	129	
141	3·42	10·5	145	136	151	146	
142	3·38	12·4	100	101	101	96	Slightly rusty and dusty. Sample from near surface.

1931

AREA COVERED

The territory covered by the investigation in 1931 comprises that part of the province lying south of the St. Lawrence River, between the Lévis-Armstrong highway and the end of Gaspe Peninsula. In the beginning of the field season a few days were spent in going over parts left unfinished in the previous field season in Bagot, Drummond, and Lotbinière Counties.

Two hundred and forty deposits were examined and one hundred samples were collected for testing.

CONDITIONS AFFECTING ROAD DEVELOPMENT

Outside of a narrow strip of low, level land bordering the St. Lawrence River, the territory under consideration is an undulating highland in its southwestern end and becomes gradually more hilly towards the northeast. From its southwestern end to Lake Témiscouata, the central part of the highland is occupied by a narrow range of low hills, which forms the dividing line between the St. Lawrence River and the St. John River watersheds. Northeast of the lake, the hills extend over the full width of the territory, except for the narrow belt of lowland bordering the St. Lawrence. This belt becomes gradually narrower towards the northeast and beyond Matane the full width of the Gaspe Peninsula, which forms the northeastern end of the area, is occupied by high hills, with the exception of a narrow strip of rolling country bordering the Bay of Chaleur.

The denser and more prosperous settlements are found in the St. Lawrence lowland. In the early days of settlement of the country this was the only easily accessible part of the territory and was the first to be occupied by settlers. For a long time it remained the only occupied land, outside of a few fishermen's settlements scattered along the Gaspe coast. Active establishment of permanent settlements in the interior did not begin until the middle of the nineteenth century. On account of the hilly character of the country, settlements were confined to certain areas of comparatively easy access such as river valleys and tracts of fairly level land. The southwestern end of the territory was more favourable for such development because of its more even topography, larger tracts of land with soil suitable for cultivation, and lesser distance to the older centres of population. Since 1860, the settlement in that part was further encouraged by the opening up of colonization roads by the Provincial government. One of these, the Taché road, was built 20 miles from the St. Lawrence River road and parallel to it, and ran northeastward as far as Lake Pohenagamuk, at the border between Kamouraska and Témiscouata Counties. At intervals of from 10 to 20 miles, the two parallel roads were connected by cross-roads. Occupation progressed at a slower rate than had been anticipated and covered only part of the area made accessible by these roads. At present, no part of the interior is as thickly populated as the St. Lawrence lowland, although settlements are fairly continuous throughout the southwest end of the area, that is, Dorchester and Bellechasse Counties. In Montmagny and L'Islet, there are large stretches of wooded land immediately southeast of the St. Lawrence lowland, with scattered settlements towards the rear end of the counties. The interior of Kamouraska is as yet very sparsely settled. In Témiscouata, there is a line of comparatively old settlements along the route of the Témiscouata railway, which runs from Rivière du Loup to Edmundston. The opening up and occupation of that part of the highland bordering the St. Lawrence lowland has also progressed farther into the interior than in the neighbouring counties, but most of the interior, outside of the vicinity of the railway line, is sparsely settled. Farther northeast, permanent establishments are confined to the coast or its immediate vicinity, except along the route of the Intercolonial (now Canadian National) railway, where settlements form an almost continuous line from the St. Lawrence lowland to the Matapedia-Bonaventure border. In order to encourage the back-to-the-land movement which started a few years ago, the Provincial department of colonization built several roads in unsettled territory. These roads penetrate into the interior along river valleys or through comparatively gently sloping land, so that the new settlers have easy access to outside points.

ROAD CONDITIONS

The road running along the shore of the St. Lawrence River from Lévis to St. Flavie traverses the older and denser settlements and is the more important line of highway travel in the territory. Most of the through traffic goes over this road. At Rivière du Loup a road leads off from the river and follows the route of the Témiscouata railway to New Brunswick, serving as a connecting link with the Maritime Provinces. This and the river road are part of the Trans-Canada highway. At St. Flavie, another road leads off from the river and follows the route of the Canadian National railway to New Brunswick. The St. Flavie and Rivière du Loup roads carry all the interprovincial traffic. The continuation eastward from St. Flavie of the river road encircles the whole Gaspe Peninsula. It was only recently reconstructed and is not as much travelled as west of St. Flavie, but the amount of traffic during the tourist season is increasing at a rapid rate, as the road traverses a country that presents a scenic beauty unsurpassed anywhere else in eastern Canada. In the southwestern end of the area, from Lévis to St. Jean Port Joli, several roads leading into the interior carry a fairly large amount of local traffic. Two of these, the St. Vallier-St. Camille and the St. Jean-St. Pamphile roads, have recently been absorbed into the Provincial highway system. All these roads are connected at their southern end, near the International border, with another highway also recently included in the Provincial system, and which runs from St. Pamphile to St. Georges de Beauce, or approximately parallel to the main river-road. All the provincial roads, and several secondary roads, are now improved over their entire length, while the mileage of improved surface is rapidly increasing on many other secondary roads.

The St. Lawrence River road runs through level land all the way from Lévis to Rivière du Loup, with the exception of a few miles outside of Lévis, where long, gentle grades are encountered, and back of St. André, where the road comes down a steep escarpment to almost river level at the village. The road is now paved with bituminous concrete between Lévis and Montmagny, and paving work is being continued eastward from Montmagny and will eventually reach Rivière du Loup. With the exception of the Lévis-Montmagny section and a few other sections through towns or villages, which are paved with either bituminous concrete or bituminous macadam, the remainder is surfaced with gravel, and on account of the rapid increase in the amount of traffic, particularly since the opening up of the Gaspe Peninsula to motor vehicles, the maintenance of the gravel surface in proper condition has become a difficult problem. Even with continuous patrol maintenance, the road between Montmagny and Rivière du Loup was generally in poor condition in the summer of 1931. At that time of the year, the traffic consists largely of fast-moving motor vehicles. The eastern end, where the traffic is comparatively lighter and the average quality of the gravel better, is in somewhat better condition than the western end. The lack of good gravel, as well as the heavy traffic, is responsible for the present condition of the road. From Lévis to the L'Islet-Kamouraska border, there are many small and shallow deposits of gravel, most of which contain a large proportion of soft shale or slate. Although some of them are fairly satisfactory on roads of light traffic, none of them can stand the river road traffic. Gravels Nos. 637, 638 and 640 lying east of St. André in Kamouraska County are among the best available between Lévis and Rivière du Loup, apart from a few deposits worked solely for concrete aggregate, such as Nos. 619 and 623. They wear rather fast on the main road, but smooth and hard surfaces have been built with these gravels on roads of lesser traffic. Other deposits in this county are either very soft or very sandy, the latter corrugating badly under fast traffic. Beach gravels have proved as good as the better bank gravels, but are available at a few points only along the shore and in limited amount. The paving of the river road as far as Rivière du Loup will do away with the expensive maintenance of the present gravel surface, and will solve the problem of getting suitable material. Except for a few large ones, most of the gravel deposits are becoming rapidly exhausted. There is, however, an enormous amount of stone in the numerous steep ledges, ridges and knolls found almost everywhere. The steep faces of the exposures make quarrying easy, with little stripping, and the crushed stone makes a good aggregate for pavements.

The Rivière du Loup-St. Flavie road goes through level land most of the way, with a few gentle grades between St. Simon and Rimouski, and rather steep grades where the road crosses the River Boisbouscaché at Tobin and the River du Sud between St. Fabien and Bic.

The road is on the whole in fair condition. Except near Rivière du Loup and Rimouski the traffic is not too great, but is rapidly increasing every year. Both sides of Rivière du Loup, the road is badly corrugated in places and maintenance is a difficult problem on account of the large amount of traffic and poor quality of gravel. From Trois Pistoles to St. Fabien, the road while fairly smooth, is soft and wears fast. Local gravel forms shallow deposits, and with the exception of No. 689, is soft and sandy. From Rimouski to St. Flavie, the road is surfaced with beach gravel, which can be easily obtained anywhere along the shore from Father

Point eastward, and is in very good condition, with the exception of a three-mile stretch from the town limits of Rimouski to Rimouski Wharf, where local traffic is fairly large. Under normal conditions this stretch can be maintained in proper shape with beach gravel, but during a prolonged spell of dry weather in the late summer of 1931, when tourist traffic was at its height, considerable difficulty was experienced in keeping the gravel from being thrown to the sides by the fast-moving vehicles, and the road was eventually covered with a thin layer of clayey sand as binding medium, in order to keep the gravel in place. Good road gravels are found at only a few points along the Rivière du Loup-St. Flavie road. Nos. 685, 686, 688, 690, 691 and 693 are among the more suitable for road purposes. No. 687 is used solely as railway ballast, but should prove a good road material. On account of the great depth of the deposit, the gravel is fresher and harder than that seen in the road pits. Beach gravel is available only in the eastern end, where it has been used with good results.

The Rivière du Loup-Edmundston road runs through level land for about 4 miles outside of Rivière du Loup, then rises gradually, with long, slight grades, reaching an elevation of over 1,300 feet at its highest point in the village of St. Honoré. From there to St. Rose, a few steep grades are encountered, but on the whole the road keeps to fairly level land. From St. Rose to the New Brunswick boundary, it follows a strip of perfectly level land bordering the Madawaska River.

The road is all the way surfaced with gravel and is in very good condition, with the exception of a four-mile stretch of straight, level road just outside of Rivière du Loup. This stretch, part of which passes through a peat bog, carries a large amount of local traffic, and in the summer of 1931 was in poor condition, markedly corrugated and very dusty. Good gravel is fairly common all along this road as far as the New Brunswick border, and traffic is on the average lighter than on the river road. Particularly good stretches of road have been built with gravels Nos. 655, 658, 659, 660 and 664 in St. Honoré, St. Louis, Cabano, Notre Dame, and St. Rose.

After leaving the St. Lawrence lowland, the St. Flavie-Matapedia road rises gradually to the height of land at St. Moise, and then enters the Matapedia valley, which it follows all the way to New Brunswick. Although the country around is hilly most of the way, the road is either level or slopes gently. The steeper grades are encountered near the St. Lawrence, where the road after leaving the river shore ascends a series of low, steep-faced terraces. The condition of the road, which is surfaced with gravel over its entire length, is for the most part very good. In many places the surface wears fast, due largely to the softness of the gravel pebbles. Traffic is comparatively light as yet, particularly between St. Florence and Matapedia, where the country is for the most part unsettled, but has increased at a rapid rate in the last few years, since the opening up of the Gaspe region to motor travel. Gravels are fairly common throughout the Matapedia valley, but scarce from Lake Matapedia to the St. Lawrence. They are as a rule well graded, compact readily on the road, and make a smooth surface. With the exception of a few deposits, however, roads built with these gravels soften appreciably when in a wet condition, and wear fast even when dry. This is due mostly to the large proportion of soft shale or shaly limestone common to all these gravels, particularly those between St. Florence and Matapedia, Nos. 709, 713, 718 (D. Pelletier's pit, Amqui), 719, 722, 723 (A. Dufour's pit, Causapscal) and 725 are the few deposits with gravel harder than the average. These have been used with good results, although in some cases the road surfaces were not so smooth as those made out of the softer gravels. Good beach gravel from the shore of the St. Lawrence is used for surfacing the road from St. Flavie to St. Joseph.

The road around the Gaspe Peninsula runs through fairly level land from St. Flavie to St. Anne des Monts. From there to Gaspe, the country is very hilly and long grades are numerous, some of them fairly steep. From Gaspe to Matapedia, the road traverses gently rolling country, with an occasional stretch of level land, and grades are for the most part easy. The road is surfaced with gravel all the way, except within the limits of a few towns and villages that are paved. Tourist traffic is increasing very rapidly and is now fairly large in the middle of the summer, but very light at other times. The volume of traffic, particularly local traffic, is larger on the south shore of the peninsula than on the north shore. The road is in good condition all the way, more so in the hilly part of the north shore, which was more recently improved than the remainder of the road, and upon which traffic proceeds at reduced speed, down grade as well as up grade. Bank gravel is exceedingly scarce along the north shore, being found only at the mouth of some of the larger rivers, and is very poorly graded from the road standpoint. Beach gravel, however, is available almost anywhere along the coast, and is the only material used for surfacing the road all the way from St. Flavie to Cap des Rosiers. This gravel is fairly uniform in coarseness and composition and made up of quartzite, quartzose sandstone, and slate, the slate seemingly keeping the road surface properly compacted and bonded. It has given good results, except in a few places between Metis and Matane, where it is made up largely of hard quartzose rocks, and difficulty was experienced during a long, dry spell of weather in the latter part of the summer of 1931 in having the gravel properly compacted on the road and keeping the surface from unravelling under traffic. The south shore is also surfaced with beach gravel wherever available, or all the way except between Broadlands and St. Jean, around the Gaspe Bay and a few other short stretches. Beach gravel is not so uniform as along the north shore, but except in a few places where too coarse material was used, it has made good and durable road surfaces. No. 763 is a large bar of particularly good beach gravel, between Barachois and Coin du Banc. Between Broadlands and St. Jean, there are a number of good bank gravel deposits, including Nos. 733, 735, 736, 737, 739 and 740. Around the Gaspe Bay, there is no beach gravel and even bank gravel, which is used entirely, is scarce. Some of the gravels used around the bay hold much friable sandstone, which crumbles readily under traffic, and the sand-clay-like surface, though smooth, is dusty and wears fast. Except in the west end, bank gravels are on the whole scarce along the south shore road. There may be a large amount of good bank gravel such as Nos. 751 and 753 farther inland, particularly along the many streams, but the abundant supply of beach gravel near the road has made it unnecessary to go far afield in search of road material.

In the southwest part of the territory, there are a number of roads that have been recently improved over their entire length. Some of them are part of the Provincial system of highways, others are secondary roads. One of these roads runs from St. Georges to St. Pamphile, in a direction approximately parallel to the St. Lawrence River road, and the others lead off at different points from the St. Lawrence road inland to near the International border: they are the St. Henri-St. Germaine, Beaumont-St. Philémon, St. Vallier-St. Camille, L'Islet-St. Adalbert, St. Jean-St. Pamphile and St. Alexandre-Rivière Bleue roads. The St. Georges-St. Pamphile road passes through high land all the way, almost level in Bellechasse and Montmagny Counties, gently rolling with an occasional fairly steep grade in Dorchester and L'Islet Counties. The St. Henri-St. Germaine road follows level land to St. Malachie station, then passes rather abruptly into the high land. The other roads run through level land for only a few miles after they leave the St. Lawrence River, and then pass gradually into the high land. Throughout the high land, grades are almost continuous and some fairly steep along the St. Henri-St. Germaine, Beaumont-St. Philémon, St. Vallier-St. Camille roads, and at both ends of the L'Islet-St. Adalbert road, whereas longer and gentler grades, with occasional level stretches are encountered along the St. Jean-St. Pamphile, St. Alexandre-Rivière Bleue roads and the centre part of the L'Islet-St. Adalbert road. The northwest slopes are as a rule steeper than the southeast slopes, due to the general southeast dip of the country rocks. All these roads carry rather light traffic, except the St. Vallier-St. Camille and St. Jean-St. Pamphile roads, where traffic reaches a maximum of over 300 vehicles per day in midsummer. They are surfaced with gravel over their entire length, with the exception of the villages of St. Anselme, St. Charles, St. Gervais and St. Raphael, which are paved, and a five-mile stretch between St. Rose and St. Germaine station, which is surfaced with partly disintegrated slate, loosened from outcrops and broken up by ploughing along the direction of lamination, the lamination plane being almost vertical. It is applied to the road in the same manner as gravel, and makes a smoother and less dusty surface than gravel. In the summer of 1931 this stretch was in excellent condition, better than any gravel surface, but the material is not hard enough to stand the wear of a good gravel surface. Both main and secondary roads are under constant patrol-maintenance and are generally kept in good condition.

In the more undulating parts of the southwestern end of the territory, it is the usual practice to haul road gravel in winter and stock it in piles at the higher points along the road, so that when road work is started in the spring, only a short down-hill haul is necessary to bring the material where needed. There are several advantages to this. Most of the deposits are located along streams in valley bottoms, with steep up-hill grades from deposit to road. In many cases the land around the deposits is saturated with water in late spring and early summer, making hauling almost impossible at a time when gravel is more urgently needed. In winter the deposits are more easily accessible, and the hauling is done through fields along lines of easy grade, enabling larger loads to be carried. Labour also is more readily available in winter. On account of the heavy snowfall throughout the territory, however, the work of clearing the pits from snow after each storm is a serious drawback.

The St. Georges-St. Pamphile road, which is a provincial highway, has not yet been built all the way up to the standard for that class of road as regards sub-base grading and drainage, and width of travelled way. The road surface in some of the steep grades encountered in L'Islet County is somewhat rough, owing to rain water running over the surface in places, and washing away the fine material. Between the Beauce-Dorchester County border and St. Justine, the gravel is loose at many places, wears rather fast, and the road is dusty. There is little gravel found along this section, and most of it is poor. Calcium chloride applied on some stretches, particularly through built-up sections, greatly improves conditions in keeping down the dust and holding the gravel in place. Elsewhere the road is in good condition, and most of gravels used are of good quality.

The only unimproved stretch on the St. Henri-St. Germaine road had just been surfaced with gravel when this road was visited in the summer of 1931. Rather coarse gravel from deposit No. 540 was used, as is the usual practice in the first improvement of an earth road, the coarse material serving as a foundation course for further improvement with finer gravel. Outside of this newly improved portion, where the gravel was still loose when inspected, the road is in good condition, but wears fast in places, particularly between St. Henri and St. Anselme, where the traffic is much heavier than the average for this road, and where the only gravel available carries much soft, red shale or slate, and also a few stretches near St. Léon, surfaced with soft schist gravel. Whereas all gravels used make a good road surface, some of them carry a rather high proportion of friable material. Nos. 553, 537 and 540 are harder and more durable than the others.

The Beaumont-St. Philémon road is in good condition all the way but the surface wears fast and is dusty in the low level land between Beaumont and past St. Gervais, where the traffic is greater than on the remainder of the road, and the gravel soft and shaly. On a section of the road adjoining the main river-road, the gravel pebbles crumble readily under traffic and the surface looks almost like a sand-clay road. Throughout the high land the road is in excellent condition and the gravel of good quality, although some are rather soft, on account of their large proportion of schist, such as No. 554. The road built with this gravel is very good, almost as smooth and impervious as a bituminous surface, but is said to soften considerably during the spring thawing.

Except for several miles around St. Raphael, the St. Vallier-St. Camille road is all in good condition. Near St. Raphael the road surface, although fairly good, is corrugated in places, and loose in others. Gravel is plentiful throughout this district, is for the most part made up of large pebbles and sand with but little intermediate size material, and takes long to compact properly on the road. This irregularity of grading is more pronounced in some deposits than others. Near the St. Lawrence River, gravel is similar to that in other parts of the low land, being made up mostly of soft shale. The road surfaced with this gravel is good and smooth but wears fast and is somewhat dusty. The gravel has a deeper red colour than elsewhere and is said to stain vehicles when the road surface is wet. Very good stretches of road are seen in the high land, particularly around St. Philémon, where gravel is common for miles to the east and west, although not all of it is equally suitable. The better phase, represented by No. 565, makes a smooth road that remains firm even when wet.

The L'Islet-St. Adalbert and St. Alexandre-Rivière Bleue roads traverse wooded or sparsely settled country over most of their way and carry very light traffic. Both roads are in good condition, but some of the gravels used are very sandy and, though quite satisfactory under present conditions, would not stand too much traffic. The thickly wooded country and comparatively small amount of gravel needed make it impracticable and unnecessary to go beyond the immediate vicinity of the road for material, but as the land becomes more opened up, other and probably better deposits will be developed. Deposits of good gravel have been worked in the settled part at both ends of these two roads.

Traffic on the St. Jean-St. Pamphile road reaches a maximum of over 300 vehicles per day in midsummer, and is rather light at other times. Outside of a group of deposits around St. Damase and a few between Tourville and St. Perpétue, little gravel has been found near the road. From St. Damase, the road runs through woods as far as Tourville, and through sparsely settled territory farther on, outside of two fairly large groups of settlements around St. Perpétue and St. Pamphile, so that it is not practicable over most of the way to go far from the road in search of material. According to road patrolmen, all the cleared up land has been fairly thoroughly searched for gravel, particularly around St. Pamphile, and only a few small deposits found, hardly enough to supply present requirements.

ROAD GRAVELS

The larger part of the more important deposits examined have been sampled and tested, and the results tabled at the end of this report. In the column "Remarks" are given the general character, amount available, and wearing quality of most of the gravels tested. The following brief description by counties supplements the information given in the tables and should be read in conjunction with them.

Bagot County

The investigation of the gravels of this county was made in 1930 and included in the report for that year, with the exception of a large deposit northeast of St. Nazaire, close to the county border. Gravel was in the past taken from this deposit for ballast by the Intercolonial (now Canadian National) Railway, but its use was discontinued, because the material had a tendency to cement together, particularly at the surface. The spur line that connects the pit to the main line at Duncan Station has not been removed and is now used as siding. During the last few years several pits, including No. 519, have been opened for surfacing local roads. This gravel compacts readily and makes a smooth and firm surface, but wears fast and forms dust. The deposit occupies the edge of a bluff facing south and is underlain by drift, which forms the lower part of the bluff.

Dorchester County

There is a considerable amount of gravel for miles along the banks of the Chaudière River, in both Dorchester and Lévis Counties. All the gravel used in surfacing the road along the left bank of the river between St. Maxime and St. Etienne was taken at a number of places from this nearly continuous deposit. This road has been included in the Provincial system since the opening of the Quebec bridge to vehicular traffic, as it leads the northbound traffic towards Quebec directly to the bridge. Rather coarse gravel was used, as is the usual practice in the surfacing of a newly improved road, the coarse material serving as foundation course for further improvement with finer gravel. In general, the gravel is coarser in Dorchester, and becomes gradually finer and more sandy down the river, in Lévis County. In its coarser phase, represented by sample No. 530, the gravel carries about 50 per cent sand and more as the gravel becomes finer; in places there is much sand interstratified with the gravel. Although extending for some distance along the river, the deposit is narrow and does not average more than 8 feet in depth. It has better wearing quality than the gravels found closer to the St. Lawrence, which carry much shale.

Along the Etchemin River, there is a large deposit or group of deposits between St. Claire and the mouth of the Abenakis River, from which good road gravel has been obtained. Samples Nos. 533 and 534 are from these deposits. Nos. 532 (Laliberté's pit, St. Claire), 536 and 537 are other good gravels found elsewhere along the same river. Some of the Etchemin River deposits carry also much sand interstratified with the gravel. No. 540 is a large deposit, in which the material varies from coarse and bouldery to almost straight sand, but holds much good road gravel of suitable coarseness. In the southeast part of the county, gravel is much scarcer and generally poor. Nos. 541 (Samson's pit, St. Rose) and 544 are better than the average for that part.

Bellechasse County

There are a large number of deposits in the central part of the county and between St. Raphael and Lafayette. Elsewhere gravels are less common, and most of the deposits near the St. Lawrence River are shallow and small.

The gravels in the central part extend from St. Damien to St. Paul, past the county border. Coarseness varies a great deal between the different deposits, some being coarse and bouldery, and others carrying more sand than gravel. Except where too sandy, they compact readily on the road, make smooth and hard surfaces, even when wet, and are fairly durable. Very good roads have been built with these gravels around St. Damien, St. Philémon and St. Paul. A few of the gravels wear faster than the others, due to the large proportion of soft schist and slate. Samples Nos. 556, 564 (Campagnon's pit, Buckland), 565 and 566 (Rouillard's pit, St. Philémon) are representative of the harder gravel, and Nos. 554, 557 and 568 (Nicol's pit, St. Philémon) are from the softer gravel.

Between Lafayette and St. Raphael good gravels, somewhat similar to those near St. Philémon, are found near St. Cajétan, including Nos. 562 and 563 (Cadran's pit, St. Cajétan). Farther north, gravel is not so well graded and is slow to compact properly on the road, with the exception of No. 559, which is better in that respect than other local gravels.

In the low land bordering the St. Lawrence, gravel occurs in the form of very low ridges. Most of the deposits are small and shallow and several of them are now exhausted. They carry from 50 to 75 per cent of rather soft red and green shale or slate, are very well graded although rather fine, pack well and make smooth roads, but wear fast. Some of them, such as No. 545 (Jacques' pit, Beaumont) and two highway pits southeast of St. Vallier, are less shaly than the others and give satisfactory service where the traffic is not too great. When the road is wet, the red shale or slate common to all these deposits is said to stain vehicles.

Several deposits have been developed for road gravel near St. Camille and St. Magloire, in the southeast end of the county. Gravel is generally coarse, takes long to form a compact surface, but has good wearing qualities. One deposit northwest of St. Magloire holds fine, well graded, hard gravel.

Montmagny County

Except around St. Paul, Lac Frontière, and south of Montmagny, gravels are scarce, at least throughout the settled part.

The group of deposits found around St. Paul forms the eastern end of the large gravel area in the central part of Bellechasse County. The gravel is similar in composition to that in the adjoining part of Bellechasse County, but much finer, in fact is made up largely of very coarse sand. It makes a firm and smooth road surface, even smoother than the roads built with the Bellechasse gravels, and stands satisfactorily the wear of traffic, which is lighter than in the adjoining part of Bellechasse. There are a number of gravel deposits between Lac Frontière and Panet, some of which have yielded good surfacing material. They compact readily on the road, make smooth surfaces, and although only moderately durable, wear well under traffic. In the south corner of the county, good road gravel has been obtained from two deposits lying between the main road and the Daaquam River, including No. 581, and also from the river bed.

South of Montmagny, there are several deposits lying a short distance from the foot of a high, steep escarpment, which marks the southeast limit of the St. Lawrence lowland. They carry a high proportion of friable, grey sandstone, which crumbles readily under traffic, and makes the road surface very sandy. No. 576 compacts more firmly than the others, particularly on clay soils. In a shallow deposit near St. Pierre, hard, coarse, red sandstone is found in addition to the soft, grey sandstone. A stretch of road built with this material was firmer than stretches surfaced with other local gravels.

L'Islet County

Several deposits occur near St. Damase, at the foot of an escarpment that marks the limit between the low and the high lands. In the remainder of the low land, deposits are fairly common, but most of them are small and shallow. In the high land there are several deposits scattered around St. Marcel, St. Adalbert, and Ste. Perpétue de L'Islet. Elsewhere, gravel is scarce, leaving out of consideration large areas of wooded land.

Much good gravel has been taken from three deposits along Trois Saumons River at St. Damase. The material takes long to consolidate on the road, but makes a hard, slow-wearing surface. One of the deposits is turning very sandy and is now worked mostly for concrete sand. No. 598 occurring farther north along the St. Jean River is a softer gravel that packs more readily than the others. Its use is confined to roads of very light traffic, where it has proved good.

Most of the gravels found in the remainder of the low land, although well graded, carry much soft shale or slate, and stand only very light traffic. Nos. 593 (Fournier's pit, St. Jean), 594 (Bois' pit, St. Aubert) and 602 are less shaly or slaty than the others. No. 589 is rather sandy, but free from shale or slate and makes a smooth, hard surface, unaffected by weather conditions.

In the southern corner of the county, from St. Marcel to half way between St. Adalbert and St. Pamphile, several deposits have been worked for road gravel, and good road surfaces built with most of them. The quality of some of the gravels can not yet be judged by service tests, on account of the short time in use and very light traffic prevailing locally. Coarseness varies a great deal in most of the deposits, and a few are decidedly too sandy, but it may be safely said that outside of the few very sandy ones, they are all suitable under traffic conditions prevailing at present. Of the St. Perpétue deposits, three are of large size and carry fresh and hard, but very sandy gravel, and another, along the road to Taché, is of small size and the gravel is poorly graded and compacts unevenly. The three sandy gravels have been extensively used for road surfacing, as they are the only gravels found fairly close to the main road, for miles in both directions. The road surface built with these gravels is firm and smooth, if not very durable.

Kamouraska County

Gravels are fairly common in the St. Lawrence lowland except between Rivière Ouelle and St. André, where no bank gravel is found for a distance of 2 to 5 miles inland, but there is a limited amount of beach gravel at a few points along the shore. A few deposits are also found in a narrow belt of high land along the southeast edge of the lowland. The remainder of the county is almost everywhere wooded and was not examined, except a few deposits along the St. Alexandre-Rivière Bleue road.

Most of the gravels examined are rather poor, because of being irregularly graded and sandy, and in the case of a few, very soft. The only gravels used with a fair amount of success are found east of St. André, including Nos. 637, 638, 639 (Caron's pit), 640, and one northeast of St. Pascal (Morneau's pit). Good and durable road surfaces have been made with these gravels on roads of light traffic, although none of them will stand successfully the wear of the main road traffic. Two other good road gravel deposits along the St. Alexandre-Rivière Bleue road are located three-quarters of a mile and 3 miles north of the Transcontinental (Canadian National) railway, and are owned by the highway department. Nos. 619 and 623 are used entirely for concrete aggregate.

The main highway follows alternate routes between Ste. Anne and St. André. The older, in date of improvement, runs inland through St. Pacôme, St. Philippe, St. Pascal, and Ste. Hélène, whereas the other follows the shore most of the way. Except for stretches freshly surfaced, where the material is all loose, the shore road is in better condition, and less corrugated and dusty than the older road. This is due not only to the lighter traffic, but also to the better grading and wearing quality of the beach gravel used.

Témiscouata County

Gravels are found throughout the settled parts, with the exception of a portion of the high land in the northeast part of the county. They are particularly common in a long ridge, or succession of knolls, extending from St. Antonin northeast to past St. Epiphane. A number of large deposits also occurs between St. Honoré and the New Brunswick border, between Estcourt and the New Brunswick border, southwest of St. Hubert and northwest of St. Eloi. Near the St. Lawrence all deposits are of small size and gravel of poor quality, excepting however the St. Eloi deposits and No. 688. Gravel has been dug at many places in the knolls between St. Antonin and St. Epiphane, and a considerable amount used, mostly on local roads. Where care was taken not to use too sandy material, smooth and hard road-surfaces have been built, even on the main road from Rivière du Loup, which passes at the southwest end of the gravel area. Gravel from No. 670 was used on a section of that road from outside of the town limits of Rivière du Loup to several miles past the pit. The bad condition of a straight and level stretch of that road observed in the late summer of 1931 was mainly due to the amount and character of traffic, combined with a prolonged spell of dry weather. Between St. Honoré and the New Brunswick border, there are several large deposits and smaller ones. The gravel from the larger ones, such as Nos. 655, 658, 659, 660 and 664, has been used in making some of the best stretches of roads seen anywhere in the district. Some of the deposits between Estcourt and the New Brunswick border are of large size, but in No. 650, what is left appears to be mostly coarse sand. Good gravel has been obtained from all the deposits, the small as well as the large, judging by the condition of the local roads, but the gravel from the shallower deposits is more weathered and dusty than that from the deeper. The district was visited during a spell of dry weather that prevailed for several weeks, and all roads were dusty, but otherwise good. No. 652 is a very large deposit in the shape of a horse's back, along the shore of Grande Fourche Lake, southwest of St. Hubert. The material makes a smooth and firm road surface which wears evenly but rather fast, and is dusty. On the road from St. Honoré to Lamy there is much gravel, mostly coarse and bouldery, in a ridge that runs parallel to the road. Good road gravel is seen in a large railway ballast pit in deposit No. 687, northwest of St. Eloi. Part of the deposit, which is of large size, is owned by the Canadian National Railways and worked solely for ballast. Gravel for road purposes is obtained from two smaller deposits, Nos. 685 and 686, near the village of St. Eloi. No. 685 is sandy and works best on clay roads. No. 686

is well graded but does not bind firmly on light soils. Both have given good results on local clay roads. Gravel from the large deposit, No. 687, although not yet tried on roads, is evidently better for that purpose than other local gravels. No. 688 is a medium size deposit which holds better gravel than the average found locally.

Rimouski County

A large number of small gravel deposits is found in that part of the county near the St. Lawrence River, and 9 of moderate to fairly large size are scattered throughout the same area. The majority of the deposits are poor road material, carrying either too much soft slate or too much sand. Nos. 690, 699 (Bégin's pit, Sacré Cœur), 701 and 705 are some of the larger deposits with good gravel. Nos. 694 (Ouellet's pit, Bic), 698 (Côté's pit, Sacré Cœur) and 707 (Paquette's pit, Luceville), which are also among the larger deposits, carry coarse and bouldery gravel but of good quality, provided the oversize material is screened out. Nos. 693, 695 (Turcotte's pit, Sacré Cœur), 703 (Proulx's pit, St. Anaclet) and 708 are deposits of smaller size, from which good road gravel has been obtained. Nos. 689, 691, 697, and 702 are sandy but the first two have been used on stretches of the main road with a fair amount of success, and the last two have proved good on roads of lesser traffic. Apart from No. 708, all the gravels just enumerated lie within three miles of the St. Lawrence River shore. Farther inland, gravels are of poor quality. Near St. Gabriel, local roads are surfaced with crushed rock. All the gravels lying west of Rimouski have been used on some stretch of the main river road, but none of those found east of that town has been used on the main road, which is entirely surfaced with beach gravel from Rimouski eastward. Beach gravel is available almost anywhere along the shore from Father Point eastward to Cap des Rosiers, in Gaspé County, as already mentioned.

Matane County

Investigation work covered only the western corner of the county and a narrow band along the coast. There is a large amount of gravel found around St. Angèle, much of it being poorly graded and soft. Good stretches of road have been built with gravel from the two large deposits, Nos. 709 and 713, and a smaller one, No. 710, which hold much better-graded gravel than the other deposits. Gravel from No. 710 and from the upper part of Nos. 709 and 713 is partly weathered, soft, and wears fast on the main road, but gives much better and more lasting results on roads of lesser traffic. A large amount of the fresher and harder gravel from No. 709 has been used, mostly on the main road, and has proved better than any other local gravel. Very little of the lower gravel from No. 713 has been used hitherto, but it should be just as good; both Nos. 709 and 713 lie in the same river bank a short distance from each other and are probably one continuous deposit.

Back of Metis, there are a few shallow and small deposits of gravel carrying a large proportion of soft shale or slate. The high, steep banks of Matane River show in places much coarse, bouldery and silty, poorly graded gravel, suitable at best for foundation work. Apart from a short stretch between St. Flavie and Metis, the shore road is all surfaced with beach gravel, better and more durable than any of the few, local bank-gravels.

Matapedia County

Investigation has been confined to the immediate vicinity of the St. Flavie-Matapedia road, and includes all deposits that have been developed to any extent. Gravel is scarce between the northern county border and Val Brillant, and plentiful from there to the southern county border. All deposits are of large size, and from the southeast end of Lake Matapedia to Causapscal gravel is seen almost anywhere in the bank of the Matapedia river. A number of pits, opened at the time that the road was first improved as a provincial highway, are now abandoned on account of the gravel either being exhausted or becoming too sandy or stony. Nearly all the pits now worked for road gravel show well graded material, but the gravel in most of them carries a rather high proportion of soft, calcareous slate or shale, packs well on the road, and makes a smooth and firm surface that wears evenly, but fast. In wet weather the road surface loses some of its firmness. Nos. 714 (Dufour's pit, St. Moise), 718 (Pelletier's pit, Amqui), 719, 722, 723 (Dufour's pit, Causapscal) and 725 are harder than the others and have made firm and durable roads, unaffected by wet weather. Coarseness in No. 722 varies much, and stretches of road built with this gravel are not so smooth as those built with the softer gravels, but screening out the oversize and proper mixing of the different sizes would partly if not wholly overcome this defect. This gravel and No. 719 also take longer to compact firmly on the road.

Bonaventure County

The investigation work was confined to a few deposits in the Matapedia valley and a narrow belt of land along the shore of the Bay of Chaleur. Of the few deposits examined in the Matapedia valley, four are of large size, three of which are in the high, steep river bank, and the other one, No. 729, in a large river-flat. Along the bay shore a number of fairly large deposits are seen between Broadlands and St. Jean and near Bonaventure; elsewhere bank gravels are much scarcer, but beach gravel is available at many points along the shore and used in surfacing long stretches of the main road.

The large deposits along the Matapedia River hold gravel that is on the average coarse and bouldery, but well graded once the oversize is screened out. The road surface built with these gravels is firm and smooth, but softens when wet, owing to the large proportion of soft slate or shale in the gravels. The road would also wear fast if subjected to the same amount of traffic as in Matapedia County. The bay-shore road is surfaced with bank gravel from Matapedia to past St. Jean, with the exception of a short stretch just east of Matapedia, which is surfaced with river gravel available in large amount at low-water level where the Matapedia empties into the Restigouche. All the more important bank deposits found as far east as St. Jean are included in the tables, to which should be added another large one, No. 741, (Gauvreau's pit), which lies opposite the railway crossing, in the village of St. Jean. All are good road gravels and most of them make durable surfaces. In the long string of deposits found over a distance of four miles between Pointe-à-la-Garde and Escuminac, and including Nos. 737 and 739, gravel pebbles are almost all very hard felsite and trap. These gravels have good wearing quality but poor cementing power, and it is found necessary to add occasionally a little clayey sand to the road surface as a binding medium. Nos. 735 and 736, lying farther west, are made up of the same material but not quite so hard, and bind more readily on the road. From west of St. Omer to near the mouth of the Cascapedia River, the shore road is entirely surfaced with fine, hard beach gravel. A railway pit in the high, steep shore bank west of Carleton, and a large side-hill road cut at the mouth of the Cascapedia River, show much more silty material and partly sorted glacial drift than regular gravel. In the road cut, the only regular gravel is found in a thick, almost vertical layer, from which good road material is obtained for the main road. Farther east and as far as Caplan River, the shore road is surfaced with sandy and in places soft gravel obtained from several local deposits. From Caplan River to near Bonaventure and from east of that place to Shigawake, beach gravel is almost entirely used on the shore road. Near the mouth of the Bonaventure River, good gravel is obtained from two large deposits, Nos. 751 and 752 (old railway pit), also from several smaller ones. All these have been used on the shore road and several other roads, and smooth, hard and durable surfaces made with them. Other deposits also occur farther up the river. From Bonaventure east to the county limits, bank gravel is scarce, at least within a few miles of the shore. A pit has just been opened (1931) in deposit No. 753, three miles inland from Shigawake, for improving local roads. The gravel is coarse and bouldery, but by screening out the oversize can be turned into a well graded material. It is a hard gravel that packs readily and firmly on the road. From Shigawake to the county limits, the shore road is surfaced with bank gravel obtained from several deposits, mostly of small size, with the exception of a few short stretches here and there covered with beach gravel. The few bank gravels found along this section are for the most part rather poor, except near Port Daniel, where a small pit (Sweetman's) shows good road material.

Gaspe County

Except around Gaspe Bay, good beach gravel is available almost anywhere along the coast, and is used on the shore road with good results, and for that reason is preferred to any other material. By far the larger deposit of beach gravel occurs in the form of a gravel bar over four miles in length between Coin du Banc and Barachois, where an unlimited supply of gravel of any desired coarseness is readily available from the shore road, which runs on top of the bar for a distance of over one mile. Sample No. 763 represents a rather fine and sandy phase used for road maintenance. Coarser gravel is used in surfacing work. It is a much harder beach gravel than found anywhere else in the county, and takes long to compact firmly, but is particularly suitable for the wearing course of a gravel surface. Bank gravel is everywhere scarce, only two large deposits being found, one near Grand Pabos, and the other one, No. 761, near Brèche-à-Manon. Good gravel is seen in these two deposits, but none has been used lately for road purposes. Around Gaspe Bay, there is no beach gravel, and the little bank gravel available is being rapidly absorbed into the roads, at least one deposit being now completely exhausted.

TABLE IV

Results of Tests on Gravels

Sample No.	Location and owner	Character of material: Composition of pebbles: Durable	Intermediate	Soft	Type of stone, per cent	Shape of pebbles	Per cent of silt and clay	Per cent of wear	Amount available.	Size of pit, cu. yds.
	Bagot County									
518	Lot 17, Con. X, Roxton tp.; A. Parent.	50	45	5	Sandstone 30; slate 25; quartzite 15.	Angular and flat.	0·6	....	Much more sand than gravel. Pit reaches sand at maximum depth of 7 feet.	3,300
519	3 miles northeast of St. Nazaire; P. Lamothe; other owners.	5	72	23	Limestone 55; calcareous shale 25.	Angular to sub-angular.	1·9	27·6	Over 100,000 cubic yards. Average depth of deposit 9 feet.	12,000 Also R.R. pit.
	Lotbinière County									
523	1½ miles southeast of St. Apollinaire; J. Gingras.	13	85	2	Shale 65; sandstone 15.	Angular......	0·6	23·4	Deposit forms flat ridge about 3 times pit size. Maximum depth of 8 feet under ridge crest.	3,000
	Lévis County									
526	St. Télesphore; P. Bégin.	40	40	20	Quartzite and sandstone 50; siliceous slate 30.	....	1·4	32·8	Small. Pit originally opened for sand. Pit reaches clay at maximum depth of 12 feet.	2,200
	Dorchester County									
530	4 miles north of St. Bernard; N. Fortier; other owners.	70	20	10	Quartzite and sandstone 55; slate and schist 20.	Angular to sub-angular.	0·5	16·4	Very large. West bank of Chaudière River gravelly for miles. As seen from several excavations drift underlies gravel at average depth of 8 feet and maximum of 15 feet.	7,000 Also other pits.

533	½ mile east of St. Claire; E. Bissonnette; other owners.	86	7	7	Quartzite 50; sandstone 15; trap 15.	Subangular...	1·0	10·9	Over 100,000 cubic yards in several knolls scattered along bank of Etchemin River. Sand underlies gravel at various depths.	17,500 Also other pits.
534	¾ mile east of St. Claire; E. Lacasse.	40	50	10	Quartzite 35; slate 30; sandstone 25.	Angular......	1·6	22·9	See No. 533..............	750
536	3 miles northwest of St. Malachie; A. Leclerc.	33	47	20	Slate 55; quartzite 40.	Angular and some flat.	1·5	....	Gravel said to cover over 3·5 acres, and pit, which averages 9 feet in depth, does not reach bottom of deposit. Overburden 2 feet of fine sand.	5,700
537	Lot 14, Con. IX, Frampton tp.; W. Kelly.	57	28	15	Quartzite 30; schist 30; trap 25.	Angular......	0·8	18·0	At least 10 times pit size. Pit reaches sand at maximum depth of 20 feet.	4,500
538	Lot 25, Con. XI, Frampton tp.; J. Gosselin.	40	20	40	Quartzite and sandstone 40; schist 30; trap 10.	Angular and some flat.	1·2	....	Very large but includes much sand. At maximum depth of 13 feet pit does not reach bottom.	1,050
540	Lot 4, Con. IV, Ware tp.; J. and A. Turmel.	55	35	10	Sandstone 25; schist 25; trap 20; quartzite 15.	Subangular to angular.	0·9	13·2	From test-pit records, 8 to 10 acres. Greatest depth in pit is over 20 feet.	13,300
544	Lot 7, Con. IX, Langevin tp.; R. Lecours.	47	53	0	Slate 35; sandstone 25; quartzite 20; trap 15.	Angular......	1·8	....	33,000 cubic yards including overburden, which is 3 to 5 feet thick. Pit has an average depth of 9 feet and reaches close to bottom.	7,100
	Bellechasse County									
549	1½ miles northeast of St. Gervais; P. Laflamme.	20	65	15	Quartzite 30; slate 30; sandstone 15; trap 10.	....	1·2	....	Gravel deposited back of brook-dam at high water. Fresh supply every year.	
550	1½ miles southeast of St. Gervais; Department of Highways.	10	73	17	Slate 55; quartzite and sandstone 35.	Angular......	1·0	30·3	Very large. Pit reaches clay at an average depth of 9 feet.	5,000
554	4 miles southeast of St. Lazare; A. and E. Mignault.	10	67	23	Schist 45; slate 40.	....	0·7	....	Unknown................	

TABLE IV—Continued

Results of Tests on Gravels—Continued

Sample No.	Location and owner	Character of material						Per cent of wear	Amount available	Size of pit, cu. yds.
		Composition of pebbles				Shape of pebbles	Per cent of silt and clay			
		Durable	Intermediate	Soft	Type of stone, per cent					
	Bellechasse Co.—Con.									
556	St. Damien; C. Lafontaine.	33	55	12	Schist and slate 45; quartzite 40.	Angular.......	1·5	15·4	Pit in steep slope of knoll, which is about 10 times pit size but may not be all gravel. More gravel below pit bottom. Pit bank up to 40 feet in height.	12,000
557	2½ miles northeast of St. Damien; A. Rouleau.	20	55	25	Schist 55; quartzite 35.	Angular.......	0·7	19·9	Deposit forms small knoll about 10 times size of pit. Pit has a maximum depth of 10 feet and does not reach bottom of deposit.	1,400
559	2½ miles southwest of St. Raphael; J. Raby.	77	18	5	Quartzite and sandstone 85.	Subangular...	0·5	7·4	One acre, with maximum depth of 9 feet at pit.	2,700
560	1¼ miles southeast of St. Raphael; E. Ménard.	55	45	0	Sandstone 55; shale or slate 25.	Angular.......	2·3	....	Deposit about 3 times size of pit, but the larger part is either too sandy or too stony. Maximum pit depth 20 feet. Overburden 1½ to 2½ feet of clayey sand.	10,000
562	Lot 12, Con. II, Armagh tp.; C. Roy.	45	45	10	Sandstone 45; quartzite 40.	Angular to subangular.	0·8	10·0	Deposit said to cover at least 2 acres, from test-pit records. Pit reaches boulder-clay at maximum depth of 12 feet.	2,000
565	1 mile northwest of St. Philémon; P. Roy.	83	12	5	Quartzite 45; schist 25; sandstone 20.	....	0·8	15·3	Deposit said to cover 1·5 acres and has a maximum depth of over 25 feet.	Large.

570	Lot 12, Con. III, Bellechasse tp.; J. Prévost.	47	50	3	Quartzite 35; slate and schist 30; sandstone 25.	....	0·8	15·1	Well over 30,000 cubic yards. Pit does not reach bottom at maximum depth of 8 feet.	400
	Montmagny County									
575	2¼ miles east of St. Pierre; A. Bernier.	60	33	7	Quartzite 50; sandstone 35.	Angular.......	1·2	....	Steep brook bank, 30 feet high, very gravelly on surface for a distance of several hundred yards. Pit cuts through upper 8 feet of bank only.	2,500
576	3½ miles south of Montmagny; U. Talbot.	55	38	7	Quartzite 45; sandstone 30; slate 20.	Angular.......	1·6	20·5	Slight ridge-like elevation runs about one mile southwest but may not be all gravel. Average depth of pit 6 feet.	9,300
581	Lot 35, Con. VII, Panet tp.; J. Foley.	45	50	5	Quartzite 30; schist 30; sandstone 15; slate 15.	Angular.......	0·3	14·3	Patrolman's estimate: 4 acres. Average depth of deposit 7·5 feet.	3,100
	L'Islet County									
589	2 miles southeast of St. Eugène; J. Théberge.	60	33	7	Sandstone 50; quartzite 40.	Angular.......	1·3	9·9	Said to cover 20,000 square yards. Pit has an average depth of 6 feet and reaches sand in places.	4,200
598	1 mile north of St. Damase; H. Gamache.	27	53	20	Slate and shale 55; sandstone 20; quartzite 20.	Angular and flat.	0·6	....	Steep knoll over 5 times size of pit. Pit does not reach bottom at maximum depth of 20 feet.	3,600
601	4 miles southwest of St. Roch; G. Pelletier, N. Ouellet.	10	70	20	Slate 75.........	Flat and angular.	0·5	32·0	At least 23,000 square yards. Pit averages 5 feet in depth, which is close to average depth of deposit.	2,600
602	4 miles southwest of St. Roch; A. Francoeur.	27	55	18	Sandstone 50; quartzite 20; slate 15.	Angular.......	0·5	14·9	Unknown, but probably very large. Covered with at least 4 feet of sand. Pit has a maximum depth of over 20 feet.	100,000
603	¾ mile southwest of St. Roch; A. Pelletier.	5	75	20	Slate 65; sandstone 30.	....	1·6	....	Said to cover several acres, from fence-post indications. Two test pits, 5 and 8 feet deep, through gravel. Deposit flat-lying and probably shallow.	Very small.

59633—10

TABLE IV—Continued

Results of Tests on Gravels—Continued

Sample No.	Location and owner	Character of material: Composition of pebbles: Durable	Intermediate	Soft	Type of stone, per cent	Shape of pebbles	Per cent of silt and clay	Per cent of wear	Amount available	Size of pit, cu. yds.
	L'Islet Co.—Con.									
609	Lot 26, Con. II, Leverrier tp.; D. Corriveau.	45	43	12	Quartzite 30; trap 30; slate 20.	Angular to subangular.	0·6	....	Ridge or horseback runs for over a mile, but said to be sand in places. Maximum depth of pit under ridge crest 18 feet.	4,900
614	Lot 21, Con. VI, Casgrain tp.; H. Jean.	45	40	15	Slate and schist 45; quartzite 20; trap 15.	Angular.......	1·2	14·3	About half exhausted. Pit reaches clay at maximum depth of 13 feet.	5,300
	Kamouraska County									
619	¾ mile southwest of St. Anne; M. Martin.	50	47	3	Slate 35; quartzite 30; sandstone 25.	Angular.......	0·6	....	About 7 acres said to be available. Pit reaches clay at maximum depth of 16 feet. Gravel covered with at least 3 feet of sand.	10,000
623	½ mile west of St. Pacôme; C.N.R.	55	33	12	Quartzite and sandstone 75; slate 20.	....	0·1	10·9	Very large. Pit reaches sand at maximum depth of 35 feet.	Very large.
626	1½ miles northeast of St. Philippe; L. Anctil.	25	30	45	Slate 45; quartzite 35.	Angular.......	0·8	....	Gravel common for several miles southwest but all small and shallow deposits.	1,000
633	3 miles southeast of St. Hélène; F. Lajoie.	70	20	10	Quartzite and sandstone 75; slate 15.	Angular.......	1·9	20·8	About 5 times size of pit, possibly much more. Pit said to reach drift at maximum depth of 8 feet.	1,500
637	1 mile south of St. André; A. St. Pierre.	57	30	13	Quartzite 65; sandstone 25.	Subangular...	0·8	14·5	Unknown but apparently very large. Pit reaches drift at maximum depth of 15 feet.	10,800 Also two other pits.

6963—10½

638	2 miles northeast of St. Andre; H. Lebel.	85	15	0	Quartzite 50; sandstone 50.	Subangular...	0·6	12·9	Apparently very large. Pit reaches drift at maximum depth of 13 feet.	12,100
640	2 miles northwest of St. Alexandre; A. Ouellet.	40	57	3	Quartzite 45; slate 35.	Angular and some flat.	0·5	17·1	Over 20 acres and average depth of 9 feet, according to road patrolman's estimate.	3,300
641	3 miles southeast of St. Alexandre; E. Lapointe	....	....	....	(Sand)........	....	1·0	....	Pit shows almost solely sand, of which there is a large amount; surface of deposit very gravelly in places.	600
	Témiscouata County									
646	1½ miles west of Estcourt; C.N.R.	65	35	0	Quartzite 55; slates (some calcareous) 20.	Angular.......	0·6	10·6	Very large. Pit has a maximum depth of 75 feet.	Over 500,000
649	¼ mile west of Rivière Bleue; J. Girard.	60	37	3	Quartzite 45; sandstone 40.	Angular.......	0·2	....	Road patrolman's estimate is about 2 acres. Pit reaches sand at maximum depth of 10 feet.	2,500
650	Aubut Station; C.N.R..	52	33	15	Quartzose and slaty metamorphic rocks	....	0·5	13·1	Very large, but probably mostly sand. Pit bottom is sandy gravel and sand.	Over 250,000
652	2¼ miles southwest of St. Hubert; A. Theriault.	25	70	5	Slaty limestone, slate and schist 70.	Angular and some flat.	1·2	....	Large horseback, several hundred thousand cubic yards in size.	3,900
655	2¾ miles east of St. Honoré; L. Lebel.	30	60	10	Quartzite and sandstone 50; slate or shale and limestone 45.	Angular to subangular.	2·1	10·1	Large horseback over one mile in length. At maximum depth of 25 feet pit does not reach bottom of deposit.	6,200
658	2 miles west of St. Louis; J. B. Pelletier.	40	45	15	Quartzite and quartzose schist 75; slate 15.	Angular and flat.	0·9	....	Over 65,000 cubic yards. Pit reaches sand and clay at maximum depth of 40 feet.	40,000
659	Just west of Cabano; J. Bérubé.	33	50	17	Sandstone 45; quartzite 30; slate 20.	Angular.......	0·9	15·7	As much as taken out. Pit reaches close to bottom of deposit at maximum depth of 18 feet. Larger deposit along lake shore in village is partly built over.	23,300

TABLE IV—Continued

Results of Tests on Gravels—Continued

Sample No.	Location and owner	Character of material						Per cent of wear	Amount available	Size of pit, cu. yds.
		Composition of pebbles				Shape of pebbles	Per cent of silt and clay			
		Durable	Intermediate	Soft	Type of stone per cent					
	Témiscouata Co.—Con.									
660	Notre Dame du Lac; M. le Curé E. Gagnon; G. Guay.	17	63	20	Slate 70; sandstone and metamorphic 20.	Angular......	1·2	16·2	Unknown but probably very large. Deposit in high, steep bluff facing lake. Pit bank up to 45 feet in height.	10,300
662	St. Rose; W. Souci......	5	70	25	Slate 85........	Flat and subangular.	1·2	17·9	Deposit half exhausted. Pit reaches drift at maximum depth of 20 feet. Several other deposits around village.	3,000
664	5¾ miles southeast of St. Rose; D. Griffin.	5	85	10	Slate 80; sandstone 15.	Flat.........	0·5	....	Long gravelly ridge or bluff facing flat land bordering river. Pit bank up to 18 feet in height.	11,200
669	2¼ miles northeast of Rivière du Loup; A. Sirois.	40	43	17	Quartzite and sandstone 70; slate 25.	Angular......	0·5	16·0	Gravel ridge covers 25,000 square yards. Pit has a maximum depth of 9 feet under ridge crest and does not reach bottom of deposit.	1,400
670	2½ miles northeast of St. Antonin; J. Bérubé.	65	35	0	Quartzite 35; slate 30; sandstone 30.	Angular to subangular.	0·6	....	Covers at least 7 acres. Pit reaches fine sand and clay at average depth of 10 feet.	19,000
671	2 miles southwest of St. Modeste; J. B. Bérubé.	35	62	3	Slate 45; quartzite 30; sandstone 25.	Angular to subangular.	0·8	13·5	Gravel knolls very common for 3 miles northeast including No. 673 and others. Pit does not reach bottom of deposit at maximum depth of 15 feet.	1,700

673	¾ miles northeast of St. Modeste; C. Beaulieu.	50	47	3	Quartzite 35; slate 35; sandstone 25.	Angular to subangular.	0·6	....	*See* No. 671. Pit reaches sand or very fine gravel at maximum depth of 25 feet.	1,800
675	Just southwest of Cacouna; E. Roy.	3	95	2	Slate 90.........	Flat and some angular.	0·2	28·8	Over 10 times size of pit. Pit has an average depth of 6 feet and reaches close to bottom of deposit.	2,100
678	St. Epiphane; A. Gagnon	70	30	0	Quartzite 60; sandstone 30.	....	0·7	10·1	Gravel knolls common for 3½ miles northeast including Nos. 680 and 681. Pit has a maximum depth of 30 feet; depth of gravel varies. Overburden 1½ to 2½ feet of silty sand.	7,900
680	2½ miles northeast of St. Epiphane; J. Gagnon.	40	42	18	Quartzite 35; sandstone 25; slate 20.	Angular.......	1·3	....	*See* No. 678. Pit has a maximum depth of over 20 feet. Overburden 1 to 2½ feet of clayey sand.	1,700
681	3½ miles northeast of St. Epiphane; O. Gagnon.	45	35	20	Quartzite 40; sandstone 35; slate 20.	Angular to subangular.	1·2	11·9	*See* No. 678. Pit does not reach bottom of deposit at maximum depth of 9 feet.	1,200
684	½ mile northwest of St. Cyprien.	27	67	6	Slaty quartzite and quartzose slate 80.	Sharply angular and some flat.	10·0	....	Very large amount of boulder-clay; gravel very scarce.	2,300
685	½ mile southwest of St. Eloi; C. Bouchard.	65	15	20	Quartzite, some slaty 55; sandstone 35.	Angular.......	0·7	....	Deposit said by owner to cover over 4 acres. Pit averages 7 feet in depth and does not quite reach bottom of deposit.	2,700
686	1 mile northwest of St. Eloi; S. Pettigrew.	55	27	18	Quartzite 45; sandstone 40.	Subangular...	1·1	....	Large gravel terrace. Deposit 10 feet in depth.	Over 2,000
687	2 miles northwest of St. Eloi; C.N.R.	75	25	0	Quartzite and sandstone 75; limestone 15.	....	0·2	6·5	....	Over 500,000
687a	" "	70	27	3	Quartzite 60; sandstone 30.	....	0·6	....	As much as taken out. Pit reaches clay at maximum depth of 22 feet.	
688	2 miles southwest of Trois Pistoles; C. Morency.	60	20	20	Quartzite 40; sandstone 20; slate and schist 20.	Angular.......	1·6	17·0	....	6,500
688a	" "	73	27	0	Quartzite and sandstone 75; slate 10.	....	4·8	....	Gravel ridge covers 12,000 square yards. Deposit averages 9 feet in depth.	

TABLE IV—Continued

Results of Tests on Gravels—Continued

Sample No.	Location and owner	Character of material						Per cent of wear	Amount available	Size of pit, cu. yds.
		Composition of pebbles				Shape of pebbles	Per cent of silt and clay			
		Durable	Intermediate	Soft	Type of stone per cent					
	Rimouski County.									
689	3½ miles southwest of St. Simon; D. Rioux.	58	30	12	Quartzite and felsite 70; schist and slate 15.	....	0·7	....	Several acres, according to road patrolman. Pit averages 4 feet in depth. Coarser gravel below pit bottom.	2,300
690	1 mile northeast of St. Fabien; F. Coulombe.	30	60	10	Quartzite 50; slate 30; limestone 20.	Angular.......	0·9	16·7	Over 2 acres. Pit has a maximum depth of 20 feet and is said not to reach bottom of deposit.	4,100
691	4½ miles northeast of St. Fabien; J. Côté.	50	33	17	Quartzite 60; sandstone 30; slate 10.	Flat and angular.	0·1	....	Unknown, but deposit apparently covers several acres. Pit reaches clay at maximum depth of 8 feet.	Over 3,000
693	½ mile south of Bic; G. Voyer.	80	15	5	Quartzite 70; sandstone 20.	Sharply angular and flat.	0·5	10·0	Covers at least 10,000 sq. yds. Pit reaches close to bottom of deposit at maximum depth of 6 feet.	2,300
697	1 mile southeast of Sacré Coeur; J. Roy.	25	63	12	Shaly sandstone and siliceous shale or slate 70.	Subangular...	0·7	....	Pit in one of several similar knolls. Extent unknown, and maximum depth 6 feet.	1,100
701	1½ miles southwest of St. Anaclet; A. Poirier.	40	50	10	Slate and limestone 55; quartzite and sandstone 45.	Subangular...	0·5	12·5	Brook bank gravelly for several hundred yards. Pit does not reach bottom of deposit at maximum depth of 10 feet. Covered with at least 2 feet of fine sand.	1,400

702	St. Anaclet; E. Heppel..	40	55	5	Slate and shale 55; slaty quartzite 30.	Angular......	1·0	....	Pit has an average depth of 7 feet and does not reach bottom of deposit. Gravelly for several miles, but gravel generally very shallow. Overburden 2 feet of coarse sand.	500
705	1 mile northeast of Luceville; A. Montgrain.	45	43	12	Quartzite and igneous 40; siliceous shale 30.	Subangular...	0·5	....	....	Over 300,000
705a	" "	45	35	20	Same as No. 705	....	1·2	....	Unknown, but probably very large. Pit not dug to bottom of deposit because hard to drain. Pit covers over 100,000 sq. yds. and averages 10 feet in depth.	
708	¾ mile southwest of St. Donat; J. Chasseur.	21	70	9	Slate 40; limestone 35.	Flat.........	0·7	....	Unknown. Pit reaches clay at maximum depth of 12 feet. Other similar deposits in vicinity, according to road patrolman.	1,500
	Matane County									
709	2½ miles northwest of St. Angèle; J. B. Gagnon.	5	50	45	Sandstone 65; slate and shale 30.	Subangular...	1·4	18·7	....	Over 20,000
709a	" "	10	90	0	Slate, shale and schist 50; limestone 40.	....	2·1	9·8	Deposit in high steep bluff, probably continuous with No. 713, 200 yds. away. Pit reaches clay or drift at maximum depth of 20 feet.	
710	1 mile west of St. Angèle; C. Pelletier.	25	33	42	Sandstone, shaly sandstone and quartzite 90.	Subangular...	1·3	18·4	At least 10 times size of pit; gravel covered with 2½ to 3 feet of clay, and underlain by clay at average depth of 9 feet.	800
713	2½ miles northwest of St. Angèle; A. Beaulieu.	45	40	15	Sandstone and quartzite 60; shale 25.	Subangular...	1·3	8·5	....	900
713a	" "	9	82	9	Limestone 45; slate and shale 30.	....	2·0	....	Gravelly bluff, over 40 feet in height, with pit in upper 12 feet. Deposit probably continuous with No. 709.	

TABLE IV—Continued

Results of Tests on Gravels—Continued

Sample No.	Location and owner	Character of material						Per cent of wear	Amount available	Size of pit, cu. yds.
		Composition of pebbles				Shape of pebbles	Per cent of silt and clay			
		Durable	Intermediate	Soft	Type of stone, per cent					
	Matapedia County									
719	2 miles southeast of Amqui; J. B. Roussel.	5	85	10	Siliceous and shaly limestone 75.	Angular to subangular.	0·4	12·7	Covers 7,500 sq. yds. Pit reaches clay at average depth of 7 feet. Gravel covered with an average of 3 feet of fine sand.	6,200
721	1 mile north of Lac au Saumon; M. Pelletier.	5	85	10	Slate or shale 75; limestone 20.	Flat and angular.	0·8	23·7	Lake shore gravelly for several miles. Pit does not reach bottom of deposit at maximum depth of 20 feet.	4,300
722	3¼ miles east of Lac au Saumon; E. Desroches	0	100	0	Hard siliceous and shaly limestone 95.	Sharply angular.	....	6·4	Deposit forms knoll at least 5 times size of pit. Pit does not reach bottom of deposit at maximum depth of 18 feet. Several other knolls around, also probably gravel.	1,600
724	½ mile north of Causapscal; E. Morissette.	0	85	15	Limestone 55; slate or shale 40.	Angular......	2·2	15·3	At least 50,000 cu. yds. Pit reaches boulder-clay at maximum depth of 18 feet.	2,100
725	Causapscal; G. Blais....	3	87	10	Limestone, more or less shaly 95.	Angular......	1·8	7·2	Deposit in steep bluff. Amount probably very large. The thickness of gravel which is 30 feet at the edge of the bluff, gradually decreases inwards.	8,300
	Bonaventure County									
729	1½ miles southeast of Routhierville; Dept. of Highways.	0	60	40	Slate or shale and limestone 80.	Flat and subangular.	1·4	24·7	Deposit in low river bank and is probably very large. Thickness above water level over 20 feet.	4,700

733	½ mile southwest of Broadlands; E. Nicol.	35	65	0	Limestone 55; trap and felsite 25.	Subangular...	0·9	4·5	Deposit in low river bank and said to extend at least 200 yds. inland. Thickness above water-level 16 feet.	70
735	2 miles north of Restigouche; F. Fraser.	80	15	5	Trap and some felsite 95.	Sharply angular.	2·3	5·6	Unknown. Looks like partly sorted drift, particularly at depth.	2,000
736	2¼ miles east of Oak Bay; J. Haynes.	80	20	0	Felsite and some trap 90.	Varies from angular to rounded.	2·3	....	Many times size of pit. Pit, dug irregularly from 5 to 15 feet in depth, does not reach bottom of deposit.	7,200
737	Pointe à la Garde; J. Pitre.	95	5	0	Felsite 50; trap 30.	Varies from angular to rounded.	2·3	5·4	....	20,000
737a	Pointe à la Garde; C.N.R.; J. Low.	95	5	0	Felsite 50; trap 30.	....	0·8	4·3	Deposit ½ to ¾ exhausted, leaving about 25,000 cu. yds. available. Average depth 12 feet. Very gravelly for miles, including Nos. 736, 737, 739 and others.	37,000
739	1½ miles southwest of Escuminac; S. Barnes.	85	12	3	Felsite and some trap 90.	Varies from angular to rounded.	2·7	....	See No. 737. Pit No. 739 reaches clay at maximum depth of 12 feet.	1,200
740	3 miles west of Nouvelle; E. Dugas; J. D'Amboise.	33	47	20	Sandstone 40; slate or shale 40.	Subangular...	2·2	14·4	Probably 6 acres. Pit reaches sand at average depth of 7 feet.	6,500
747	3 miles north of Caplan; J. Poirier.	10	70	20	Limestone 35; shale 35.	Angular to subangular.	1·1	16·6	Knoll of gravel 10 times size of pit at the least. Pit probably reaches bottom of deposit at maximum depth of 17 feet. Upper 2 to 3 feet much weathered.	3,100
751	½ mile northeast of Bonaventure; F. Arsenault.	35	65	0	Limestone 35; slate 25; trap 15.	Subangular...	0·5	6·0	One end of deposit alone covers 10,000 sq. yds. according to road patrolman. Maximum depth of gravel 17 feet.	7,000
753	3¼ miles north of St. Godefroi; E. Aubut.	10	90	0	Limestone 70; sandstone 20.	Subangular...	0·9	6·6	Deposit forms terrace or series of knolls with steep south slope: traced for over 400 yds. Pit reaches clay at maximum depth of 12 feet.	460

TABLE IV—Concluded

Results of Tests on Gravels—Concluded

Sample No.	Location and owner	Character of material						Per cent of wear	Amount available	Size of pit, cu. yds.
		Composition of pebbles				Shape of pebbles	Per cent of silt and clay			
		Durable	Intermediate	Soft	Type of stone, per cent					
	Gaspé County									
761	½ mile west of Brèche à Manon; C.N.R.	0	90	10	Limestone more or less shaly 100.	Subangular...	1·9	16·2	Unknown. Deposit averages 11 feet in depth and is underlain with drift and bedrock. Upper 2 to 4 feet is weathered and soft.	60,000
762	1¾ miles north of Coin du Banc; N. Thibeault.	85	10	5	Chert or felsite 50; quartz 45.	Angular.......	3·1	....	Probably very small. Deposit underlain with muck at average depth of 3 feet.	9,000
763	Between Barachois and Coin du Banc.	95	5	0	Chert with probably some felsite 85.	Subangular...	0·0	....	Very large. Gravel bar several miles in length.	Sea beach
766	6½ miles west of Gaspe; R. Patterson.	5	80	15	Sandstone 50; limestone 35.	Angular and rounded.	1·1	7·9	Unknown, but probably at least 10 times size of pit. Pit reaches close to bottom of deposit at maximum depth of 9 feet.	1,100
767	1¼ miles west of Gaspe; W. Kenny.	0	70	30	Sandstone 100...	....	1·1	15·7	Covers 8 acres, according to owner. Gravel looks like partly sorted drift, varies much in thickness (maximum 16 feet), and is in places thickly covered with silt (up to 10 feet.)	6,900

TABLE V
Results of Tests on Gravels

Sample No.	Granulometric Analysis: Proportion of pebble to sand: Per cent pebble	Per cent sand	Pebbles: Per cent retained on screens: 2½"	2"	1½"	1"	¾"	½"	¼"	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200 mesh	Remarks
518	41	59	0	0	15	22	10	21	32	20	19	29	26	4	1	1	Deposit carries high proportion of sand. Sample is less sandy than average. Makes a good, although sandy, road surface.
519	62	38	0	14	11	20	10	15	30	29	17	24	17	5	3	5	Rather high proportion of soft pebbles. Compacts readily and firmly on the road, but wears fast and is dusty. Some of the dust may be from the soil, since unimproved local roads are very dusty.
523	45	55	0	8	8	12	16	21	35	18	13	18	43	6	1	1	Sand rather fine. Gravel carries much shale and compacts readily on road to a very smooth surface. Although not durable is satisfactory on local roads, which carry very light traffic.
526	55	45	0	0	0	13	15	27	45	44	28	8	8	6	3	3	Pit worked largely for sand, of which there is a much larger amount than gravel. Sample is from the coarser gravel. Well graded but soft gravel.
530	48	52	0	3	8	20	17	23	29	17	14	33	29	5	1	1	Sample represents coarser phase of deposit. Coarser gravel used so far only on road along west bank of Chaudière River, presumably as a foundation course for further improvement with finer material.
533	74	26	0	4	9	37	22	17	11	24	29	23	11	6	3	4	Gravel varies much in coarseness and is very sandy. Sample is from very coarse gravel, low in sand. Gravel used on roads probably more uniformly graded and not so sandy as what is now exposed in pit face, as judged by the very good results obtained.
534	46	54	0	0	5	17	15	23	40	22	20	34	13	6	2	3	Sample represents the coarser and less sandy phase. Makes a firm, smooth, durable road surface.

TABLE V—Continued

Results of Tests on Gravels—Continued

Sample No.	Granulometric Analysis: Proportion of pebble to sand: Per cent pebble	Per cent sand	Pebbles: Per cent retained on screens: 2½"	2"	1½"	1"	¾"	½"	¼"	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200 mesh	Remarks
536	49	51	0	0	4	6	12	24	54	44	25	14	8	4	2	3	Very well graded and makes a very good road surface. Holds a rather large proportion of soft pebbles.
537	74	26	3	4	13	16	13	23	28	36	28	18	8	5	2	3	Very well graded and very good road material. Sample represents the coarser and less sandy phase.
538	40	60	0	0	8	18	11	21	42	29	26	20	14	7	2	2	Well graded but soft and wears fast. Sample slightly finer than average.
540	55	45	9	11	13	12	13	15	27	32	24	22	15	4	1	2	Well graded but holds large proportion of boulders and large pebbles. On unimproved roads, makes a firm and durable, though not smooth surface.
544	55	45	0	3	18	22	11	20	26	24	19	22	20	8	3	4	Holds much sand. Sample from better graded and less sandy phase. Does not compact readily on road.
549	60	40	0	0	2	15	13	29	41	40	24	16	9	5	3	3	Very well graded. Has more lasting quality on road than local bank gravel.
550	50	50	4	0	15	18	11	20	32	28	25	24	16	4	1	2	Carries boulders and large pebbles; otherwise well graded. Although soft and dusty, is satisfactory under light traffic.
554	29	71	0	0	5	17	10	14	54	34	33	21	9	2	0	1	Sample does not include boulders and large pebbles, of which there is a fairly large amount. Makes a very smooth and firm road surface but prolonged rains are said to make it soft and muddy. Holds large proportion of soft pebbles but gives good results under light traffic.
556	70	30	3	10	11	16	10	19	31	48	24	9	6	6	2	5	Very coarse and bouldery, but very well graded, if oversize screened out. Very good road material.
557	63	37	8	8	16	16	9	15	28	44	33	15	4	1	1	2	Same as No. 556, but more weathered and softer, due to shallower depth.

559	47	53	0	8	8	17	11	17	39	39	26	11	12	10	1	1	Well graded and of good wearing quality, but takes long to compact properly.
560	22	78	0	0	20	8	11	13	48	32	35	18	7	3	2	3	Very fine, well graded. Sample represents finer phase. Makes very smooth and firm road surface under light traffic. Too fine to be considered durable.
562	58	42	0	0	10	27	12	20	31	31	22	21	16	6	2	2	Varies much in coarseness. Gives very good results on local roads.
565	60	40	0	2	11	19	13	22	33	35	26	22	11	3	1	2	Very well graded. Does not consolidate readily, but after some time makes a very smooth, firm and hard road surface, unaffected by weather. Very good gravel.
570	60	40	7	9	13	19	12	16	24	25	21	23	19	8	2	2	Very well graded and very good, if larger stones screened out.
575	42	58	6	0	8	16	11	22	37	23	22	18	24	10	1	2	Rather sandy. Makes good but not very firm road surface.
576	59	41	5	2	6	17	14	22	34	35	25	19	11	4	2	4	Sample coarser than pit average. Makes very smooth and firm surface on local clay roads with light traffic.
581	67	33	3	9	16	20	11	16	25	36	26	23	10	3	1	1	Very coarse, with 20 per cent boulders. Well graded, if larger stones screened out. Does not consolidate readily on road, but has good wearing quality.
589	37	63	6	2	12	16	13	20	31	19	19	24	28	6	2	2	Somewhat sandy. Makes smooth, firm and durable road surface.
598	69	31	0	0	2	6	8	27	57	66	20	6	3	2	1	2	Very coarse and low in sand: sample is finer than pit average. Although holding many soft pebbles, wears well and evenly under light traffic.
601	55	45	11	6	6	16	8	14	39	32	29	24	13	1	0	1	Soft slate gravel. Consolidates readily to a very smooth surface, but will stand only very light traffic.
602	47	53	4	4	13	19	12	18	30	22	22	23	27	4	1	1	Coarse and somewhat sandy. Old railway-pit. Small amount used recently on local road makes smooth surface under very light traffic.
603	20	80	0	0	0	10	10	23	57	19	19	19	27	13	1	2	Very fine slate gravel with much fine sand. Too fine and too soft for main roads. Undeveloped deposit. Sample taken from test pit.
609	38	62	0	4	1	5	5	14	71	70	22	5	1	1	0	1	Well graded, fine gravel carrying exceedingly coarse sand. Sample finer than pit average. Compacts slowly on road under light traffic but makes very hard surface.
614	60	40	17	11	17	20	9	10	16	22	23	25	19	6	2	3	Very coarse and slightly bouldery. Compacts slowly and unevenly. Better results could be expected if larger stones were screened out.
619	36	64	0	14	8	11	10	16	41	16	20	30	28	4	1	1	Deposit carries much sand; sample represents coarser and better graded gravel. Sold exclusively as concrete aggregate, most of it being hauled to St. Anne.

TABLE V—Continued

Results of Tests on Gravels—Continued

Sample No.	Granulometric Analysis																Remarks
	Proportion of pebble to sand		Pebbles							Sand						Per cent passing 200 mesh	
			Per cent retained on screens							Per cent retained on sieves							
	Per cent pebble	Per cent sand	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
623	42	58	0	6	10	21	14	17	32	24	23	25	22	6	0	0	Varies in coarseness but all well graded. Large railway-pit: gravel found unsatisfactory for ballast and now used in making concrete pipes (circular and arched) and culvert slabs. No gravel sold.
626	21	79	0	0	1	15	15	26	43	14	21	30	28	5	1	1	Medium coarse to fine, very sandy. Easily loosened and corrugated by fast-moving traffic.
633	52	48	6	0	3	16	12	18	45	46	28	14	4	2	2	4	Varies from coarse to fine; sample from coarser and less sandy phase. Consolidates readily under very light traffic to a smooth but dusty road surface.
637	60	40	0	5	11	25	17	21	21	17	20	32	23	5	1	2	Well graded, very coarse and in places bouldery; sample finer than average. Wears well under moderately heavy, fast-moving traffic.
638	42	58	0	5	9	20	10	20	36	26	36	22	11	3	1	1	Well graded and coarse with 5 per cent boulders. On front road gravel stays loose and forms corrugations in places, due in part to traffic, in part to lack of binder.
640	52	48	0	0	6	20	14	25	35	25	27	28	17	1	1	1	Very well graded. Makes smooth, firm surface and wears well under light to moderate traffic.
641	1	99	0	0	0	0	0	0	100	4	13	29	42	10	1	1	Medium fine sand. Compacts readily on road, but surface soft and in places muddy after heavy rain.
646	42	58	6	6	13	12	9	17	37	31	35	22	8	2	1	1	Well graded, coarse and sandy. Large ballast-pit, from which a small amount of gravel has been used in road surfacing, with very good results.
649	48	52	0	0	0	8	17	28	47	32	17	16	25	9	1	0	Good, hard and durable, but takes long to compact properly under light traffic.
650	55	45	0	15	16	20	8	17	24	27	32	27	10	2	1	1	Small road-pit of coarse sand with gravel streaks in bottom of old railway-pit. Sample from coarser gravel. Packs well on road but too sandy.

652	38	62	3	3	2	20	9	20	43	25	25	22	15	9	2	2	Well graded and uniform in coarseness. Makes very smooth and firm surface, but rather dusty and durable enough only for light traffic.
655	74	26	11	6	13	20	13	17	20	37	25	18	8	2	2	8	Varies much in coarseness but on the whole very well graded. Holds about 3 per cent boulders. Sample much coarser than average. Gives excellent results on roads and is quite durable.
658	55	45	0	3	4	14	11	20	48	54	31	9	2	1	1	2	Medium coarse and very well graded. Makes very good and firm roads, but will not stand too heavy traffic.
659	55	45	2	2	5	14	11	23	43	36	23	21	15	2	1	2	Medium coarse and well graded. Compacts firmly and wears well under fairly heavy, fast-moving traffic.
660	60	40	8	0	17	17	12	18	28	36	29	19	9	3	1	3	Well graded, slate gravel. Makes very good but somewhat dusty road, and will not stand too heavy traffic.
662	60	40	3	20	15	15	10	14	23	36	34	17	5	3	2	3	Very coarse, slate gravel with 25 per cent boulders. Compacts readily but is rather soft and wears fast.
664	49	51	7	13	15	12	9	14	30	26	26	24	15	6	2	1	Well graded, fine slate gravel. Makes very smooth, well bound road surface.
669	46	54	0	6	5	17	15	19	38	29	23	17	19	10	1	1	Uniform in coarseness. Packs and wears well on local roads carrying light traffic.
670	37	63	0	22	4	15	10	15	34	25	26	28	16	3	1	1	Varies much in coarseness; generally very sandy. Makes hard and smooth surface under light traffic; does not consolidate readily on nearby main road carrying fairly heavy, fast-moving traffic.
671	60	40	0	0	11	17	16	21	35	43	34	14	4	2	1	2	Varies in coarseness but well graded: sample from coarser phase. Makes very good road under light traffic.
673	37	63	0	0	2	9	8	21	60	27	22	18	22	8	2	1	Very fine sandy gravel; sample from coarser and less sandy phase. Does not pack firmly but is satisfactory for local roads.
675	51	49	0	5	15	23	13	18	26	24	27	33	15	1	0	0	Medium coarse, well graded, soft slate gravel. Wears very fast on front road, which carries fairly heavy traffic.
678	77	23	0	2	4	14	16	24	40	64	18	6	4	3	2	3	Medium fine, well graded: sample from coarser and less sandy phase. Makes smooth, firm road and wears well.
680	35	65	7	5	7	19	11	15	36	23	26	28	16	4	1	2	Varies much in coarseness but generally coarse; well graded if larger stones screened out. Proportion of sand in sample higher than average. Good results where gravel used is not too coarse.

TABLE V—Continued

Results of Tests on Gravels—Continued

Sample No.	Granulometric Analysis: Proportion of pebble to sand: Per cent pebble	Per cent sand	Pebbles: Per cent retained on screens: 2½"	2"	1½"	1"	¾"	½"	¼"	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200 mesh	Remarks
681	70	30	3	5	10	22	15	20	25	30	21	29	8	5	3	4	Well graded and coarse: sample from coarser phase. Road recently surfaced is very smooth and firm in wheel tracks, with much loose gravel in centre. Traffic very light and mostly horse-drawn. Good road gravel.
684	41	59	18	12	7	11	9	16	27	18	15	13	13	14	10	17	Glacial drift. Makes very smooth and very hard, not too dusty road. Traffic very light. Road examined in warm, dry weather.
685	30	70	0	0	2	7	13	22	56	25	21	23	25	4	1	1	Rather high in sand. Produces decided improvement on local clay roads.
686	43	57	0	0	9	12	7	19	53	53	35	6	2	1	1	2	Very well graded and very good road gravel, although somewhat slow to bind on light soils.
687	55	45	0	8	12	19	11	20	30	28	24	26	19	3	0	0	Sample No. 687 from coarse phase; sample No. 687a from fine phase.
687a	36	64	0	0	7	18	19	22	34	25	29	29	14	1	1	1	Very well graded for road purposes. All used for railway ballast.
688	61	39	0	5	5	23	14	21	32	35	24	19	11	4	3	4	Sample No. 688 from coarser phase, upper bank; sample No. 688a from sandy phase, near bottom.
688a	40	60	0	0	12	15	9	22	42	32	28	11	8	8	5	8	On front road, carrying fairly heavy traffic, much of the gravel is loose and forms pronounced corrugations. Gives much better results on side road.
689	33	67	0	0	4	18	10	19	49	20	19	22	28	9	1	1	Rather sandy. Found more satisfactory than other local gravels, which carry much soft slate and wear fast.
690	90	10	4	1	10	30	23	20	12	37	16	14	10	8	6	9	Much variation in coarseness and generally sandy: sample from very coarse gravel with but little sand, and not so well graded as average. Makes firm road but wears rather fast under fairly heavy, fast-moving traffic.

691	27	73	4	6	0	19	10	22	39	15	19	28	31	6	1	0	Uniform in coarseness, but sandy in depth; sample from sandy gravel. Rather fine and wears fast on front road.
693	53	47	0	2	4	21	24	25	24	22	26	28	20	3	0	1	Carries low proportion of small pebbles but fairly well graded: sample slightly coarser than average. Has better wearing quality than other local gravels.
697	33	67	0	0	2	13	14	22	49	25	23	25	22	3	1	1	Carries over 75 per cent sand: sample from coarser and less sandy phase. Slow to compact and makes smooth but not firm road: too sandy.
701	53	47	0	6	13	15	13	20	33	29	29	22	14	4	1	1	Well graded, coarse. Makes very smooth and firm road under light traffic.
702	50	50	0	0	0	11	9	21	59	47	29	12	6	2	2	2	Rather sandy but otherwise well graded. Makes very smooth road, but surface softens in wet weather. Good on clay roads carrying light traffic.
705	49	51	0	0	5	18	15	22	40	33	25	14	20	6	1	1	Sample No. 705 from depth of 9 feet; sample No. 705a from near surface.
705a	40	60	0	0	2	10	10	23	55	29	26	16	21	5	1	2	Old railway-pit, now worked for road gravel. Well graded, but upper part rather soft and sandy. Lower gravel wears well where traffic is light.
708	33	67	0	0	9	12	9	19	51	25	23	21	22	7	1	1	Well graded but weathered and soft in upper bank: sample from fresher gravel in lower bank. On local clay roads with light traffic, compacts very firmly and makes particularly smooth surface.
709	53	47	0	3	10	22	15	21	29	25	19	25	22	5	1	3	Sample No. 709 from upper bank: sample No. 709a from near bottom.
709a	70	30	11	1	13	16	13	16	29	54	26	8	2	2	1	7	Upper gravel uniformly well graded, but partly weathered and rather soft; lower gravel varies much in coarseness but generally well graded and fresh. Lower gravel packs more readily and makes a more durable and less dusty road surface than upper gravel. The pebble composition is different in both gravels.
710	67	33	4	4	18	23	9	19	23	33	25	25	10	2	1	4	Well graded but soft. Part of pebbles crumble under light traffic and gravel forms smooth but fast-wearing road surface, slightly muddy when wet.
713	82	18	0	2	14	27	18	17	22	56	20	4	3	6	4	7	Sample No. 713 from near pit bottom; sample No. 713a from upper bank.
713a	61	39	0	3	5	22	14	22	34	37	24	20	9	3	2	5	Coarse and well graded throughout. Small amount used on local road has given very good results. Pebble composition different in upper and lower gravel.

TABLE V—Continued

Results of Tests on Gravels—Continued

Sample No.	Granulometric Analysis: Proportion of pebble to sand: Per cent pebble	Per cent sand	Pebbles: Per cent retained on screens: 2½"	2"	1½"	1"	¾"	½"	¼"	Sand: Per cent retained on sieves: 8	14	28	48	100	200	Per cent passing 200 mesh	Remarks
719	57	43	0	0	14	23	16	20	27	29	21	26	18	4	1	1	Fairly well graded, although low in small pebbles. Makes a good, hard road, even when wet. Low proportion of small pebbles responsible for slight roughness of surface.
721	72	28	2	9	7	19	13	19	31	41	19	14	12	8	3	3	Varies in coarseness with layers, but on the whole fairly uniform and well graded. Packs readily on road and makes a very smooth, hard surface, but wears rather fast under fairly heavy, fast-moving traffic.
722	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Varies much in coarseness, but generally coarse and well graded, although low in sand and small pebbles. Makes a very hard, firm and durable road surface, but coarseness of gravel and low proportion of sand cause the surface to be slightly rough.
724	68	32	5	21	17	21	7	12	17	36	31	17	5	3	1	7	Very coarse and bouldery, but well graded if larger stones screened out. Pit recently opened. Gravel similar to No. 725, but softer, as judged by wear test in Table IV.
725	65	35	4	2	14	15	10	20	35	41	27	18	6	2	1	5	Varies much in coarseness but generally very well graded. Gives very good results on roads. Packs readily and forms firm and very smooth surface, unaffected by rain. Wears well under fairly heavy traffic.
729	72	28	18	6	15	22	12	11	16	30	24	20	14	5	2	5	Very coarse and bouldery, with about one-third boulders. Soft gravel, part of the pebbles crumbling under traffic. Packs very readily and forms very smooth surface, very hard and firm when dry, but softened by rain. Wears rather fast.

733	78	22	4	5	17	21	14	19	20	23	10	21	30	9	3	4	Uniformly very coarse, low in sand and small pebbles; well graded if larger stones screened out. Pit just opened. Looks like very good road material.
735	55	45	1	6	11	27	14	18	23	19	11	12	23	23	7	5	Partly sorted glacial drift, very uniform in coarseness but poorly graded. Compacts readily and firmly on road and makes hard surface, smooth when dry, but much softened in rainy weather. Wears well under light traffic.
736	25	75	0	0	4	22	19	20	35	21	29	21	13	9	4	3	Very fine and hard gravel, with much variation *re* proportion of sand and grading. The better graded and less sandy material, as represented by the sample, is used with good success in road-maintenance.
737	54	46	0	0	4	14	18	26	38	30	22	18	16	5	4	5	Sample No. 737 from upper bank; sample No. 737a from middle bank.
737a	62	38	0	0	4	21	22	26	27	26	21	24	22	4	1	2	Uniformly well graded, coarse, hard gravel. Takes long to compact under traffic. As a stabilizing and binding medium, a little clayey sand is added with good results.
739	46	54	3	0	10	22	12	17	36	28	24	17	15	7	4	5	Much the same as No. 737.
740	57	43	0	0	11	22	13	20	34	36	19	12	10	14	4	5	Uniform in coarseness and on the whole well graded. Consolidates readily on road and remains firm even when wet.
747	63	37	6	2	15	23	16	17	21	21	17	33	20	4	2	3	Very coarse and bouldery, with 10 per cent boulders, but fairly well graded. Packs well and wears evenly on local roads under light traffic.
751	75	25	0	7	9	23	16	22	23	36	17	21	19	4	1	2	Uniformly coarse and well graded: sample less sandy than average. Gravel makes hard, durable road, unaffected by rain.
753	69	31	3	8	27	19	13	13	17	26	23	26	17	4	1	3	Uniformly very coarse and bouldery, with over 25 per cent boulders, and low proportion of small pebbles. Pit just opened. Packs readily and firmly under light traffic. Very good as foundation course and should be equally good as surface course if larger stones were screened out.
761	53	47	0	0	11	19	12	21	37	39	29	19	6	2	1	4	Uniformly coarse and very well graded. Old railway-pit, from which a limited amount of gravel has been taken and used on main road with very good results.
762	56	44	0	0	0	3	7	31	59	32	12	11	23	12	3	7	Very fine, rather sandy, very hard gravel: sample from coarser and less sandy phase. Makes very good road surface, which remains very firm even when wet.

TABLE V—Concluded

Results of Tests on Gravels—Concluded

Sample No.	Granulometric Analysis																Remarks
	Proportion of pebble to sand		Pebbles							Sand						Per cent passing 200 mesh	
			Per cent retained on screens							Per cent retained on sieves							
	Per cent pebble	Per cent sand	2½"	2"	1½"	1"	¾"	½"	¼"	8	14	28	48	100	200		
763	21	79	0	0	0	5	5	13	77	50	36	11	3	0	0	0	Very well graded and very hard. Does not compact readily on road but makes smooth and hard surface, unaffected by rain.
766	64	36	0	0	7	21	24	22	26	27	18	22	17	10	3	3	Coarse and fairly well graded. Makes very smooth, sand-clay-like road, firmer and more durable than surfaces built out of other local gravels.
767	88	12	3	10	18	26	14	12	17	53	11	4	6	12	5	9	Partly sorted glacial drift: varies much in coarseness: sample much less sandy and harder than average. Makes very smooth road, like sand-clay road, part of the pebbles crumbling readily under traffic. Surface not so hard as the average gravel road; wears fast and is dusty.

TABLE VI

Mortar Tests*

Sample No.	Fineness modulus	Sand mortar: 1 cement: 3 sand					Remarks
		Per cent of water used	Tensile strength, per cent of standard		Compressive strength, per cent of standard		
			7 days	28 days	7 days	28 days	
519	3·24	15·1	109	109	134	157	Sample from near surface; partly weathered and rather soft.
530	3·03	12·7	116	105	152	175	
534	3·24	12·5	102	109	127	164	
536	3·82	11·7	163	144	191	175	
537	3·67	12·8	120	120	163	185	
538	3·44	11·3	116	130	137	163	
540	3·56	11·4	134	130	181	209	
557	4·06	12·5	77	89	96	137	Sample includes partly weathered material from near surface.
559	3·66	10·9	105	129	146	157	
560	3·71	11·9	159	144	209	180	
565	3·70	12·4	137	115	144	184	Sample from stock-pile.
575	3·15	14·9	23	53	25	53	Sample from near surface includes some rusty material.
576	3·58	14·9	80	86	89	113	Sample includes partly weathered material.
581	3·76	10·7	155	133	170	202	
589	3·05	12·1	111	108	150	185	
601	3·75	11·3	109	103	89	80	Sand grains mostly flat slate, hence low compressive strength.
602	3·25	11·5	120	137	134	125	
603	2·95	13·8	102	104	134	117	Fresh but rather fine; sample from test-pit dump.
609	4·56	10·5	118	121	160	145	Very coarse, slightly weathered.
614	3·21	12·3	127	125	151	176	
619	3·10	13·0	129	133	114	117	
623	3·37	12·5	120	130	130	161	
626	3·05	13·8	73	84	96	100	Sample from near surface of shallow deposit.
637	3·12	12·0	121	121	112	127	
638	3·65	11·7	113	123	167	185	
640	3·52	13·8	63	91	92	115	Sample from shallow deposit includes partly weatherd material.
641	2·53	15·1	88	95	91	96	Fresh but too fine.
646	3·79	12·4	148	142	150	174	
650	3·66	11·9	41	57	67	104	Very coarse and clean; low result may be due to friable slate.
652	3·30	12·8	118	145	144	144	
655	3·57	13·8	155	127	171	170	Very coarse; slightly clayey.
658	4·26	12·1	148	137	156	127	
659	3·67	12·1	159	131	175	184	

*For explanation, see footnote, page 123.

TABLE VI—*Concluded*

Mortar Tests*—Concluded

Sample No.	Fineness modulus	Sand mortar: 1 cement: 3 sand					Remarks
		Per cent of water used	Tensile strength, per cent of standard		Compressive strength, per cent of standard		
			7 days	28 days	7 days	28 days	
660	3·74	12·7	137	143	130	160	Very coarse; slightly clayey.
664	3·42	12·3	127	125	130	115	Sand grains largely slate.
669	3·36	12·4	111	128	167	157	
670	3·48	12·1	120	131	157	153	
671	4·03	11·9	121	117	174	145	Very coarse, slightly weathered and clayey.
673	3·29	13·8	155	133	183	152	
678	4·21	12·8	152	132	194	156	Very coarse, slightly clayey.
680	3·39	13·0	150	135	167	139	Slightly clayey but otherwise clean.
681	3·42	13·8	107	127	170	147	
686	4·28	12·7	111	92	171	155	Sample from near surface; very coarse, slightly dusty.
687	3·55	12·3	132	149	145	191	
687a	3·57	11·4	145	157	176	165	
688a	3·29	19·3	61	76	87	92	Low result due to clay and silt.
689	3·07	12·7	79	92	126	123	Sample includes partly weathered material.
691	3·03	12·4	86	92	120	111	Sample includes some partly weathered and rusty material.
701	3·59	12·4	130	135	134	152	Large amount of shell fragments.
702	4·01	13·8	136	129	136	120	Large amount of shell fragments.
705	3·53	13·0	130	140	164	150	Large amount of shell fragments.
708	3·31	13·8	136	132	116	105	Clean; sand grains mostly flat slate.
709a	4·04	13·8	150	122	185	195	Very coarse; slightly clayey.
713	3·84	12·8	148	135	190	202	Very coarse; slightly clayey.
719	3·47	12·8	136	125	135	165	
725	3·81	13·8	148	140	219	175	Very coarse; fresh and slightly clayey.
729	3·39	17·2	107	113	115	122	Sand grains mostly shale or slate; soft and slightly clayey.
733	2·87	14·9	113	118	141	163	Clean and fresh but rather fine.
735	2·44	15·5	77	81	82	99	Too fine.
736	3·19	13·8	118	127	150	160	
737a	3·34	13·8	98	96	131	161	Sand grains slightly dust coated.
740	3·26	16·3	116	107	137	125	Sample includes partly weathered material.
747	3·16	12·8	159	123	165	177	
751	3·53	11·1	173	151	160	205	
753	3·38	12·5	143	123	192	217	Slightly clayey.
761	3·82	11·7	179	139	224	169	Very coarse; slightly dusty.
763	4·33	11·0	137	121	199	171	
766	3·17	13·8	120	111	111	166	

BIBLIOGRAPHY

REPORTS DEALING WITH CERAMICS AND ROAD MATERIALS PUBLISHED BY DEPARTMENT OF MINES

The following lists of publications of the Department of Mines deal with:

(A) The clay industry of Canada and the resources of clay, shale, and certain minerals used in the ceramic industries, and

(B) Road materials.

Those which are marked * are out of print, but may be consulted at many of the public libraries throughout the country.

Reports issued by the Mines Branch may be obtained on application to the Director of the Mines Branch, and those issued by the Geological Survey may be obtained on application to the Director of the Geological Survey.

(A) CERAMICS

MINES BRANCH PUBLICATIONS

Report No.

*8. Clays and shales of Manitoba: their industrial value, Preliminary report on. By J. W. Wells, 1905.

336. Notes on clay deposits near McMurray, Alberta. By S. C. Ells, 1915.

401. Feldspar in Canada. By H. S. de Schmid, 1916.

468. Clay resources of southern Saskatchewan. By N. B. Davis, 1918.

549. Structural materials along the St. Lawrence River between Prescott, Ont., and Lachine, Que. By J. Keele and L. Heber Cole, 1922.

555. Silica in Canada: its occurrence, exploitation, and uses. Part I —Eastern Canada. By L. Heber Cole, 1923.

*626. Bentonite. By H. S. Spence, 1924.

686. Silica in Canada: its occurrence, exploitation, and uses. Part II —Western Canada. By L. Heber Cole, 1928.

723-2. Possible industrial applications for bentonite. By H. S. Spence and Margaret Light, 1931.

729. Clay and shale resources, Turner Valley and nearby districts. By W. G. Worcester, 1932.

731. Feldspar in Canada. By H. S. Spence, 1932.

*List of manufacturers of clay products.

59633—12½

Report No.

Memorandum Series

*5. Pottery clays in Canada, May, 1922.

24. Selected list of books for the brickyard office. January, 1926.

33. Preliminary report on an investigation of the treatment of certain western clays to overcome drying defects. April, 1928.

41. The clays of Canada. September, 1930.

44. Ceramic testing and research laboratories, Ottawa. February, 1931.

57. Refractory clays of Canada, 1932.

Annual Reports

421. Summary report of the Mines Branch for 1915.
Clay and shale deposits of northern Ontario.
Equipment of the ceramic laboratory.
Industrial values of clay and shale deposits in the Moncton map-area, New Brunswick.
Clays of southern Saskatchewan.

454. Summary report of the Mines Branch for 1916.
Kaolin deposits, St. Remi d'Amherst, Que.
Apatite: A substitute for bone ash in the manufacture of bone china.
Refractory materials in Canada.
Clay and shales from Pembina mountains in southern Manitoba.
Clay investigation in southern Saskatchewan.
Quartzite grinding pebbles.

493. Summary report of the Mines Branch for 1917.
Investigation of clay and shale resources, Nova Scotia, New Brunswick, northern Ontario (with special reference to the fireclays of the Missinaibi and Mattagami Rivers), Manitoba, and British Columbia.
Pottery clays.
Magnesite.
Silica.

*509. Summary report of the Mines Branch for 1918.
Tests on certain clays from British Columbia and Ontario.

542. Summary report of the Mines Branch for 1919.
Tests on various clays from British Columbia.
Clays and shale in the vicinity of Fort William and Port Arthur, Ont.
Kaolin in Gatineau valley, Que.
Aluminium and its sources.
Structural materials in Dundas, Stormont, and Glengarry Counties, eastern Ontario.
Pottery clays.

574. Summary report of investigations made by the Mines Branch during the calendar year ending December 31, 1920.
Reports on clays from various parts of Canada.
Pottery clays.
Clay-working industry (structural materials), special clay wares, white tableware.
Field examination and testing of clays.

*List of manufacturers of clay products.

Report No.

586. Summary report of investigations made by the Mines Branch during the calendar year ending December 31, 1921.

Reports on clays from various parts of Canada.
Pottery clays.
Art pottery industry.
Scum on face bricks.
Working stony clays for brick and tile.
Method for sampling clay deposits.
Clay-working industry in Canada.
Ball clay in southern Saskatchewan.

605. Summary report of investigations made by the Mines Branch during the calendar year ending December 31, 1922.

Notes on ceramic materials.

619. Investigations in ceramics and road materials, 1923.

Ceramic exhibit for the British Empire Exhibition.
Reports on clays from various parts of Canada.
Tunnel kilns for burning brick.

645. Investigations in ceramics and road materials, 1924.

Ceramic industry in the Maritime Provinces.
Reports on clays from various parts of Canada.
Cost of burning brick and tile in Ontario and Quebec.

672. Investigations in ceramics and road materials, 1925.

Some clay-working plants in Nova Scotia, New Brunswick, and Quebec.
Andalusite in Nova Scotia.
Causes and prevention of scumming and efflorescence.
Texture of ceramic materials.

690. Investigations in ceramics and road materials, 1926.

Brick sizes in Canada.
Methods of using barium for scum-prevention in stiff-mud brick.
Manufacture of grey brick.
Refractoriness of moulding sand.
Kaolin and associated clays of Punk Island, Manitoba.

697. Investigations in ceramics and road materials, 1927.

Investigation on the treatment of certain western clays to overcome drying defects.
Preliminary report on clay gathering.
Clays and shales of the Grand Lake area, New Brunswick.

722. Investigations in ceramics and road materials, 1928-1929.

Ceramic bodies for electrical heating devices.
Transverse strength of ball clay-sand and ball clay-flint mixtures.
Production of grey brick.
Clays and shales of Prince Edward Island.
Progress report on clay gathering.
Continuation of the investigation of the treatment of clays to overcome drying defects.
Plant trials to overcome drying difficulties.

Report No.

726 . Investigations in ceramics and road materials, 1930-1931.

Ceramic bodies for electrical heating devices.
Colour control of brick.
Roofing-tile clays and shales of eastern Canada.
Sodium silicate as a bonding agent for soapstone dust.
Treatment of clays to overcome drying defects.

GEOLOGICAL SURVEY PUBLICATIONS

Memoir No.

16 E. Clay and shale deposits of Nova Scotia and portions of New Brunswick. By Heinrich Ries and Joseph Keele, 1911.

24 E. Preliminary report on the clay and shale deposits of the western provinces. By Heinrich Ries and Joseph Keele, 1912.

25. Report on the clay and shale deposits of the western provinces, Part II. By Heinrich Ries and Joseph Keele, 1913.

44. Clay and shale deposits of New Brunswick. By Joseph Keele, 1914.

47. Report on the clay and shale deposits of the western provinces, Part III. By Heinrich Ries, 1914.

64. Preliminary report on the clay and shale deposits of the Province of Quebec. By Joseph Keele, 1915.

65. Report on the clay and shale deposits of the western provinces, Part IV. By Heinrich Ries, 1915.

66. Report on the clay and shale deposits of the western provinces, Part V. By Joseph Keele, 1915.

98. Magnesite deposits of Grenville district, Argenteuil County, Quebec. By M. E. Wilson, 1917.

113. Geology and mineral (kaolin) deposits of a part of Amherst Township, Quebec. By M. E. Wilson, 1919.

142. Preliminary report on the clay and shale deposits of Ontario. By Joseph Keele, 1924.

(B) ROAD MATERIALS

MINES BRANCH PUBLICATIONS

Report No.

530. Road materials along the St. Lawrence River, from the Quebec boundary to Cardinal, Ont. By R. H. Picher, 1920.

684. Use of Alberta bituminous sands for surfacing highways. By S. C. Ells, 1927.

Annual Reports

493. Summary report of the Mines Branch for 1917.

Comparison of the road materials laboratories with other laboratories.
Sampling and testing of fieldstone.
Bedrock in the city of Montreal.

Report No.

*509. Summary report of the Mines Branch for 1918.
General limiting values for broken stone.
Interpretation of results of physical tests.
Results of tests on bedrock and gravel in Nova Scotia, Quebec, Ontario, Manitoba, Alberta, and British Columbia.
Alberta bituminous sands for rural roads.

542. Summary report of the Mines Branch for 1919.
Road materials and soil conditions in Manitoba.
Road materials in Rocky Mountains Park, Alberta.
Road materials in Chateauguay and Beauharnois Counties, Quebec, from Morrisburg to Renfrew, and between Prescott and Kingston, Ontario.

574. Summary report of investigations made by the Mines Branch during the calendar year ending December 31, 1920.
Road materials, Gananoque-Napanee section, Ontario.
Road materials in Nova Scotia.

586. Summary report of investigations made by the Mines Branch during the calendar year ending December 13, 1921.
Laboratory tests on road building stone and gravel.
Road material surveys in Nova Scotia; Prescott and Russell Counties, Ontario; and Rocky Mountains Park, Alberta.

605. Summary report of investigations made by the Mines Branch during the calendar year ending December 31, 1922.
Road material surveys in Nova Scotia; and Rocky Mountains Park, Alberta.
Crushing strength of rock.

619. Investigations in ceramics and road materials, 1923.
Road materials in Quebec and Ontario.
Road material surveys in Nova Scotia and New Brunswick.

645. Investigations in ceramics and road materials, 1924.
Road material surveys, Nova Scotia and New Brunswick.

672. Investigations in ceramics and road materials, 1925.
Commercial crushed stone in eastern Ontario.
Gravel and gravel roads.

690. Investigations in ceramics and road materials, 1926.
Commercial crushed stone, Ontario and Quebec.
Stone and its use in road construction.

697. Investigations in ceramics and road materials, 1927.
Road materials in Prince Edward Island.
Stone quarries in Quebec.
The testing of non-bituminous road materials.

697-1. The testing of non-bituminous road materials.

722. Investigations in ceramics and road materials, 1928-1929.
Road materials in Prince Edward Island.
Road materials in Quebec.
Lime treatment for gumbo roads.

*List of manufacturers of clay products.

Report No.

726. Investigations in ceramics and road materials, 1930-1931.
Road gravels in Quebec.

Memorandum Series

27. Gravel and gravel roads, May, 1926.

GEOLOGICAL SURVEY PUBLICATIONS

Memoir No.

85. Road material surveys in 1914. By L. Reinecke.

99. Road material surveys in 1915. By L. Reinecke.

106. Road materials in a portion of Vaudreuil County, Quebec, and along the St. Lawrence River from the Quebec boundary to Cardinal, Ontario. By R. H. Picher.

107. Road materials in the vicinity of Regina, Saskatchewan. By L. Reinecke.

114. Road materials surveys in the city and district of Montreal, Quebec. By H. Gauthier.

INDEX

PAGE

Abbotsford.....97, 111
Acton tp.....99, 112, 113
Abenakis R..... 133
Acton Vale..... 105
Amqui..... 150
Anctil, L..... 146
Apollinaire Station..... 57
Armagh tp..... 142
Arseneault, F..... 151
Arthur, R.....87, 107
Aubut, E..... 151
Aubut Station..... 145

Bagot county,—
  Gravel.....97, 111, 132, 140
  Stone quarries..... 105
Ball, C.....97, 111
Ball clay,—
  In electric stove-plates..... 7, 8
  In slip coatings..... 33
Bannan, A..... 90
Barachois..... 139
Barnes, G.....95, 110
Barnes, S..... 151
Barry, S.....86, 106
Beach gravels.....127, 128, 129, 137
Beauharnois county.....88, 107
Beaulieu, A..... 149
Beaulieu, C..... 147
Beaumont..... 134
Beaumont-St. Philémon road.....130, 131
Bechard, R..... 91
Bégin, P..... 140
Bégin pit..... 137
Bellechasse county, gravels..126, 133, 141, 142
Bellechasse tp..... 143
Benoit, U.....94, 110
Bernier, A..... 145
Bérubé, J.....145, 146
Bérubé, J. B..... 146
Bic..... 148
Bisaillon, Mrs..... 113
Bisson, T.....90, 108
Bissonnette, E..... 141
Blais, G..... 150
Bolton tp.....100, 113
Breault, B.....92, 109
Breault, F. X.....97, 111
Breault, J.....94, 109
Brèche-à-Manon.....139, 152
Brick. *See also* Clays, drying of.
  Colour control of, rept. by L. P. Collin. 29-36
  Refractory. *See* Refractory brick.
Broadlands..... 151
Brome county.....99, 100, 113
Brome tp.....100, 113
Brown, F.....87, 106
Brunet, J.....87, 106
Buckland..... 133
Buff brick..... 33-35

Cabano..... 145
Cacouna..... 147
Cadran pit..... 134
Cairnside.....89, 107
California, magnesite, anal..... 12
Campagnon pit..... 133
Canada, roofing-tile production..... 39

PAGE

Canadian National Railways, gravel pits.....86, 90, 106, 108, 136, 144, 145, 147, 151, 152
Canrobert..... 96
Caplan..... 151
Caplan R..... 139
Carleton county, clays.....60, 63
Caron pit..... 135
Cascapedia R..... 139
Casgrain tp..... 144
Causapscal..... 150
Caza, O..... 86
Ceramic bodies for electrical heating devices, rept. by L. P. Collin..... 5-28
Chaleur Bay,—
  Clay..... 52
  Gravels.....125, 138
Chamberlain, John..... 52
Chambly county,—
  Gravels.....93, 109
  Stone quarry..... 105
Champagne, H.....99, 112
Champlain clay, suitable for roofing-tile. 63
Charlottetown..... 48
Chasseur, J..... 151
Chateauguay county.....89, 90, 107, 108
Chatham, N. B..... 56
Chaudière R..... 133
Chemicals, effect on coloration of brick.. 30
China clay,—
  In electric stove-plates..... 7, 8
  In slip coating..... 33
  Missinaibi R..... 3
Chipman, N. B..... 33
Citadel Brick, Ltd.....31, 32
Clergue, F. H..... 93
Clays and shales in Canada, suitable for roofing-tile, rept. on..... 37-66
Clays, treatment of, to overcome drying defects, rept. on..... 75-83
Clouatre, P..... 95
Coates, D..... 113
Coderre, A. A..... 95
Coin du Banc.....139, 152
Collin, L. P..... 1, 2
  Rept. by on ceramic bodies for electrical heating devices..... 5-28
  Rept. by on colour control of brick.... 29-36
Colour control of brick, rept. by L. P. Collin..... 29-36
Coloured glass..... 30
Corriveau, D..... 144
Côté, J..... 148
Coulombe, F..... 148
Cowansville.....95, 110
Cracking of clay ware, causes..... 75
Cretaceous clays..... 63
Cyr, E.....91, 108

D'Amboise, J..... 151
Degraw Stowe Co..... 13
Deneault, C.....92, 109
Deslandes, M.....98, 111
Desmarais, A.....98, 112
Desourdy, R..... 111
Desroches, E..... 152
Devonian age, shales in..... 59

PAGE

Dorchester county, gravels.......126, 133, 140
Dominion Experimental Farm........... 48
Dominion Sand and Stone Co..........103, 115
Douglasburg........................... 91
Drying defects of clays, treatment to overcome, rept. on.................... 75–83
Drummond county...................103, 115
Dubreuil, A...........................98, 112
Dufferin county, clays.................. 62
Dufour, A, pit.........................129, 138
Dufour pit, St. Moise.................... 138
Dugas, E................................ 153
Dundas county, clays.................... 63
Dundee tp.........................85, 86, 106
Dunham tp..........................95, 110
Durham county, clays................... 64
Durham tp., gravels.................103, 115

Eastman............................... 100
Edwards, C. B......................88, 107
Electrical heating devices, ceramic bodies for, rept. on.................... 5–28
Elgin tp............................87, 106
Ely tp.................................. 114
Estcourt............................... 147
Escuminac............................. 151
Estevan clay, drying characteristics.....78, 79
Estevan Coal and Brick Co. *See* International Clay Products Co.......
Etchemin R.........................133, 141

Farnham West......................... 110
Ferland, E............................. 114
Ferric chloride in tender-drying clays.... 78, 81, 82, 83
"Flashing", effect on coloration.......... 29
Foley, J............................... 145
Fortier, N............................. 140
Fortin, N...........................91, 108
Fournier pit............................ 135
Frampton tp........................... 141
Francoeur, A........................... 143
Franklin tp.........................87, 107
Fraser, F............................... 153
Fréchette, Howells, review of investigations conducted........................ 1–3
Frelighsburg........................95, 110

Gagnon, A. (St. Johns county)........92, 109
Gagnon, A. (Temiscouata county)...... 147
Gagnon, E.............................. 146
Gagnon, J.............................. 147
Gagnon, J. B........................... 149
Gagnon, O.............................. 147
Gamache, H............................ 143
Gaspe Bay............................. 139
Gaspe county.......................139, 152
Gaspe Peninsula....................125, 129
Gauvreau pit........................... 138
Georgian Bay........................... 60
Gervais, Z............................. 114
Gilman................................ 100
Gingras, J.............................. 140
Girard, J............................... 145
Glengarry county....................... 63
Godmanchester tp...................86, 106
Gosselin, J............................. 141
Goyer, E.............................93, 109
Grande Fourche Lake................... 136
Grand Pabos........................... 139
Gravels. *See also* Quebec, road gravels in.
Mortar tests on.............123–124, 163–164
Physical and screen tests on.106–122, 140–162

PAGE

Greece, magnesite, anal................. 12
Greig, D.............................89, 107
Grenville county........................ 63
Grey brick,—
Production in Canada................. 31
Maritime Provinces................. 33
Griffin, D.............................. 146
Grog. *See* Non-plastics.
Guay, G................................ 146
Guérin, H............................99, 112
Guertin, A...........................97, 111

Halton county.........................60, 62
Hastings county........................ 64
Havelock tp..........................88, 107
Hayden, R...........................88, 107
Haynes, J.............................. 153
Heat treatment on soapstone dust shapes. 71
Hemmingford tp......................88, 107
Heppel, E.............................. 151
Hinchinbrook tp.....................87, 107
Holden, Mrs. M......................... 86
Houle, F.............................91, 108
Hunt, M............................100, 113
Huntingdon county..............85–88, 106–107
Hurteau, U...........................86, 106
Hydrochloric acid, in tender-drying clays 79, 81
Hydro-magnesite, in electric stove-plates, anal., etc.................... 6, 7

Iberville county..............93, 94, 109, 110
India, magnesite, anal................12, 13
Iron oxide.............................. 30

Jacques pit............................. 134
Jean, H................................ 144
Johnson Mount.......................94, 110

Kamouraska county.............126, 135, 144
Kelly, W............................... 141
Kennedy Construction Co............... 105
Kenny, W.............................. 152
Knowlton.............................. 100

Labonté, T.........................104, 115
Lacasse, E............................. 141
Lac au Saumon......................... 150
Lac Frontière.......................... 134
Laflamme, P........................... 141
Lafond, A..........................104, 115
Lafontaine, C.......................... 142
Lajoie, F............................... 144
Laliberté pit........................... 133
Lamothe, P............................ 140
Langevin tp............................ 141
Lapointe, E............................ 145
Laprairie county........................ 90
Laurin, C.............................. 110
Lawrenceville.......................... 101
Lebeau, A............................98, 111
Lebel, H............................... 145
Lebel, L................................ 145
Leblanc, J. S.........................86, 106
Leclerc, A............................. 141
Lecours, R............................. 141
Le Page, A.........................104, 115
Leverrier tp............................ 144
Levis county........................133, 140
Levis formation, shales in............... 58
Levis-St. Flavie road................... 126
Lime, in tender-drying clays............. 77
Limestone dust.......................... 31
L'Islet county..................126, 134, 143

PAGE
L'Islet-St. Adalbert road.............130, 132
Lorraine shale..........................60, 61
Lotbinière county...................... 140
Low, J.................................. 151
Luceville.............................137, 149

McLaughlin, Mrs. C..................102, 114
McLearn, Dr. F. H..................... 3
McMahon, J. F......................... 2
Rept. by, on roofing-tile clays and shales of eastern Canada............. 37-66
McMahon, M........................... 113

MacNeil, W..........................100, 113
Magnesite.............................. 3
As substitute for hydro-magnesite..... 12-14
Magnesium oxide,—
Effect of, in ceramic bodies.....6, 7, 12, 13
on thermal shock........... 13
Mainville, A..........................87, 106
Manganese dioxide......................30, 31
Maritime Provinces, grey brick production.................................33, 34
Martin, M.............................. 146
Matane county.......................137, 149
Matane R................................ 137
Matapedia county....................138, 150
Matapedia R............................ 138
Medalta Potteries........................ 83
Medicine Hat Brick Co................... 81
Menard, E.............................. 142
Mercure, A.............................. 96
Mesozoic clays, characteristics........... 50
Messier, G..........................101, 113
Metis.................................. 137
Metras, E.............................94, 110
Middle Musquodoboit...................33, 34
Mignault, A. and E..................... 141
Milton tp.............................101,113
Missisquoi county.....................95, 110
Mitchell, J. E.......................103, 115
Moisture, effect on soapstone dust shapes. 73
Montgrain, A........................... 149
Montmagny.............................. 143
Montmagny county..............126, 134, 143
Montmarquette, H.....................99, 112
Montreal clay, drying characteristics, etc....................................76, 77
Mont St. Hilaire......................97, 111
Moose, R................................ 63
Morency, C............................. 149
Morneau pit............................ 135
Morrison Bk............................. 56
Morrissette, E.......................... 150
Mortar tests.........................163-164
Muskoka Dist............................ 64

Napierville...........................91, 108
Napierville county....................90, 108
National Research Council............. 3
New Brunswick, clays for roofing-tile.... 52-57
Nicol, E................................ 151
Nicol pit............................... 133
Non-plastics, in tender-drying clays..... 81
Northumberland Strait................... 51
North Point............................. 47
Notre Dame du Lac...................... 146
Nouvelle............................... 151
Nova Scotia, clays for roofing-tile........49-52

Oak Bay................................ 151
Odelltown.............................92, 108
Ontario, clays and shales for roofing-tile. 59-65
Ontario county........................... 64

PAGE
Orton cones, temperatures............... 65
Ottawa.................................. 60
Ouellet, A.............................. 145
Ouellet, N.............................. 143

Panet tp................................ 143
Paquette pit............................ 137
Parent, A............................... 140
Patterson, R............................ 152
Paul, S..............................101, 114
Peel county, clays....................60, 62
Pelletier, A............................ 143
Pelletier, C............................ 149
Pelletier, D............................ 129
Pelletier, G............................ 143
Pelletier, J. B.......................... 145
Pelletier, M............................ 150
Pelletier pit........................... 138
Pettigrew, S............................ 147
Peterborough county..................... 64
Phillips, J. G............................ 2
Rept. by, on production of shapes from soapstone dust...................... 67-74
Rept. by, on treatment of clays to overcome drying defects............ 75-83
Picher, R. H.............................. 3
Rept. by, on road gravels in Quebec..84-164
Pickering................................ 60
Pitre, J................................ 151
Pleistocene clays......................50, 63
Pohenagamuk Lake....................... 125
Pointe à la Garde....................... 151
Poirier, A.............................. 148
Poirier, J.............................. 151
Ponds.................................... 51
Post-Glacial clays....................... 64
Potton tp............................... 113
Prescott county.......................... 63
Pressure, effect of, on bonding strength..14, 15
Prevost, J.............................. 145
Prince Edward Island,—
Clays for roofing-tile, in............... 47-49
Curve of good drying clay from........ 76
Proulx pit.............................. 137
Pyrometric cones. *See* Orton cones.

Quebec,—
Clays for roofing-tile.................. 57-59
Road gravels in, rept. on..............84-164
Quebec Dept. of Highways, gravel pits.. 94, 96, 100, 102, 104, 110, 111, 114, 115, 141, 150
Queenston shale.......................... 62

Raby, J................................. 144
Raymond, N..........................101, 114
Redcliff clay, drying characteristics of..80, 81
Reed, E.............................103, 115
Refractory brick.......................... 3
Restigouche............................. 153
Richelieu county......................... 93
Rimouski county.....................137, 148
Rioux, D................................ 148
Rivière Bleue........................... 145
Rivière du Loup......................... 146
Rivière du Loup-Edmundson road...... 128
Rivière du Loup-St. Flavie road.......127, 128
Rivière Ouelle.......................... 135
Robert, O.............................91, 108
Rodier, J.............................98, 112
Roofing-tile, rept. on clays and shales of eastern Canada suitable for............ 37-66
Rothwell Coal Co., shale from........... 33-35

PAGE

Rougemont Mt........................ 96
Rouillard pit........................ 133
Rouleau, A.......................... 142
Roulier, A.......................92, 109
Roussel, J. B........................ 150
Routhierville........................ 150
Rouville county..................96, 111
Roy, C.............................. 142
Roy, E....................87, 107, 147
Roy, J.............................. 148
Roy, P.............................. 142
Roxton Falls........................ 101
Roxton tp................101, 114, 140
Russell.............................. 60
Russell county....................60, 63
Russell tp........................... 62
Ruel Siding.......................... 58

Sacré Coeur....................137, 148

St. Adalbert........................ 135
St. Alexandre..............94, 109, 145
St. Alexandre-Rivière Bleue rd..130, 132, 135
St. Amand, J.....................99, 112
St. Anaclet......................... 148
St. Anaclet pit..................... 137
St. André.................135, 144, 145
St. Angèle......................137, 149
St. Antonin......................... 146
St. Anne............................ 144
St. Apollinaire..................... 140
St. Armand Parish.................... 95
St. Basile.......................93, 109
St. Bernard......................... 142
St. Bernard Parish...............92, 108
St. Blaise.......................92, 109
St. Bruno........................93, 109
St. Bruno Mt...............93, 105, 109
St. Bruno Quarry Co................. 105
St. Capetan......................... 134
St. Camille......................... 134
St. Charles de Bellechasse........... 57
St. Claire......................133, 141
St. Cyprien......................... 147
St. Damase......................134, 143
St. Dominique................97, 98, 111
St. Donat........................... 149
St. Eloi........................136, 147
St. Epiphane........................ 147
St. Eugene.......................... 143
St. Fabien.......................... 148
St. Flavie.......................... 126
St. Flavie-Matapedia road.......128, 138
St. Georges-St. Pamphile road...130, 131
St. Gervais......................... 141
St. Godefroi........................ 149
St. Grégoire...............94, 109, 110
St. Hélène.......................... 144
St. Henri-St. Germaine road.....130–131
St. Hilaire......................... 111
St. Hilaire Mt...................96, 111
St. Honoré.......................... 145
St. Hubert.......................... 145
St. Hyacinthe county................. 96
St. Jean R.......................... 135
St. Jean-St. Pamphile road....126, 130, 132
St. Johns........................92, 109
St. Johns county.............91, 92, 108
St. Joseph........................... 58
St. Lawrence River road............. 126
St. Lazare.......................... 141
St. Liboire......................98, 112
St. Louis........................... 145

PAGE

St. Magloire........................ 134
St. Malachie........................ 141
St. Marcel.......................... 135
St. Modeste.....................146, 147
St. Moise........................... 138
St. Nazaire......................... 140
St. Pacôme.......................... 144
St. Pascal.......................... 135
St. Perpétue de L'Islet............. 135
St. Philémon....................133, 142
St. Philippe........................ 144
Ste. Philomène.............89, 107, 108
St. Pierre.......................... 143
St. Pierre, A....................... 144
St. Raphael......................... 142
St. Rémi.........................91, 108
St. Roch............................ 143
Ste. Rose........................... 146
St. Simon........................... 148
St. Télesphore...................... 140
St. Valentin.....................92, 109
St. Vallier-St. Camille road......126, 130, 131

Salt. *See* Sodium chloride.
Salt glazing......................... 30
  Experiments........................ 35
Sampson pit......................... 133
Sarsfield............................ 60
Sawdust, in tender-drying clays...... 77
Screen analyses of gravel........153–162
Scumming, prevention of.............. 83
Shapes, production of, from soapstone dust, rept. by J. G. Phillips........ 67–74
Shefford county.................101, 113
Shefford tp................102, 113, 114
Shigawake........................... 139
Shrinkages, determination of, in ceramic bodies............................ 11
Shubenacadie...................33, 34, 35
Silica, effect of, in electric-stove plates.. 6
Silica sand, Missinaibi R.............. 3
Sillery shale (Quebec)............... 57
Simcoe county........................ 64
Sirard, A........................... 101
Sirois, A........................... 146
Size of soapstone dust, effect on strength. 72
Slip coatings........................ 30
  For grey brick..................... 32
Smallman, C.......................... 85
Smith and Stone, Ltd., tests made at... 12
Soapstone, uses of................... 67
Soapstone dust, production of ceramic shapes from, rept. by J. G. Phillips... 67–74
Sodium chloride in tender-drying clays.. 77
  See also Salt glazing.
Sodium silicate, bonding agent for soapstone dust........................... 67
Soles, J. C.....................100, 113
Souci, W............................ 146
Stanbridge tp....................95, 110
Stone quarries...................... 105
Stonehaven........................... 52
Stormont county...................... 63
Stoves, electric, ceramic bodies for, rept. by L. P. Collin.............. 5–28
Stove-plates, electric, requirements of.. 5, 6
Stukely tp......................102, 114
Sweetman pit........................ 139

Tache road.......................... 125
Talbot, U........................... 143
Talc, in electric stove-plates, anal., etc.. 6, 7
Temiscouata county..............136, 145

PAGE

Temiscouata Lake........................ 125
Temperature, drying effect of, soapstone dust shapes........................... 70
Tetreau, E.............................94, 109
Théberge, J............................ 143
Theriault, A............................ 143
Thermal shock,—
Effect of magnesium oxide.............12, 13
Method of testing resistance to......... 11
Thibeault, N........................... 152
Thibert, T............................89, 107
Tignish................................ 47
Toronto Brick Co....................... 31
Toughness, testing of, in ceramic bodies.. 11
Traffic, volume of, Gaspe Peninsula....129, 130
Trans-Canada highway................... 126
Tremblay, A...........................92, 109
Trois Pistoles........................... 147
Trois Saumons R........................ 135
Turcotte pit............................ 137
Turmel, A.............................. 141

United States, roofing-tile plants and production............................ 38

PAGE

Utica shales............................. 60

Valleyfield.............................. 107
Vallee, E................................ 89
Veneer coatings.......................... 30
Vercheres county......................... 93
Victoria county.......................... 64
Voyer, G................................ 148

Ware tp................................. 141
Washington, magnesite, anal............. 12
Waterloo................................ 101
Watson, Mrs...........................85, 106
Wendover tp..........................104, 115
Wickham tp...........................104, 115
White lead.............................. 33
Wilson, B.............................95, 110

Yamaska Mt............................. 96
Yamaska R...................95, 96, 110, 111
York county............................. 60

Zinc.................................... 30

622(21(06) 726,c.4 C212

Canada, mines branch reports.

726, ceramics and road materials investigations, 1930-31, ~~c. 4.~~

LOWE-MARTIN CO.—67-4026